Analysis of Water Quality Impacts from Ground Water Pump-in on the State Water Project, 1990 - 1992

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The Resources Agency State of California Department of Water Resources

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State of California
The Resources Agency
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Division of Operations and Maintenance

Pete Wilson
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David N. Kennedy
Director
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Executive Summary

Introduction

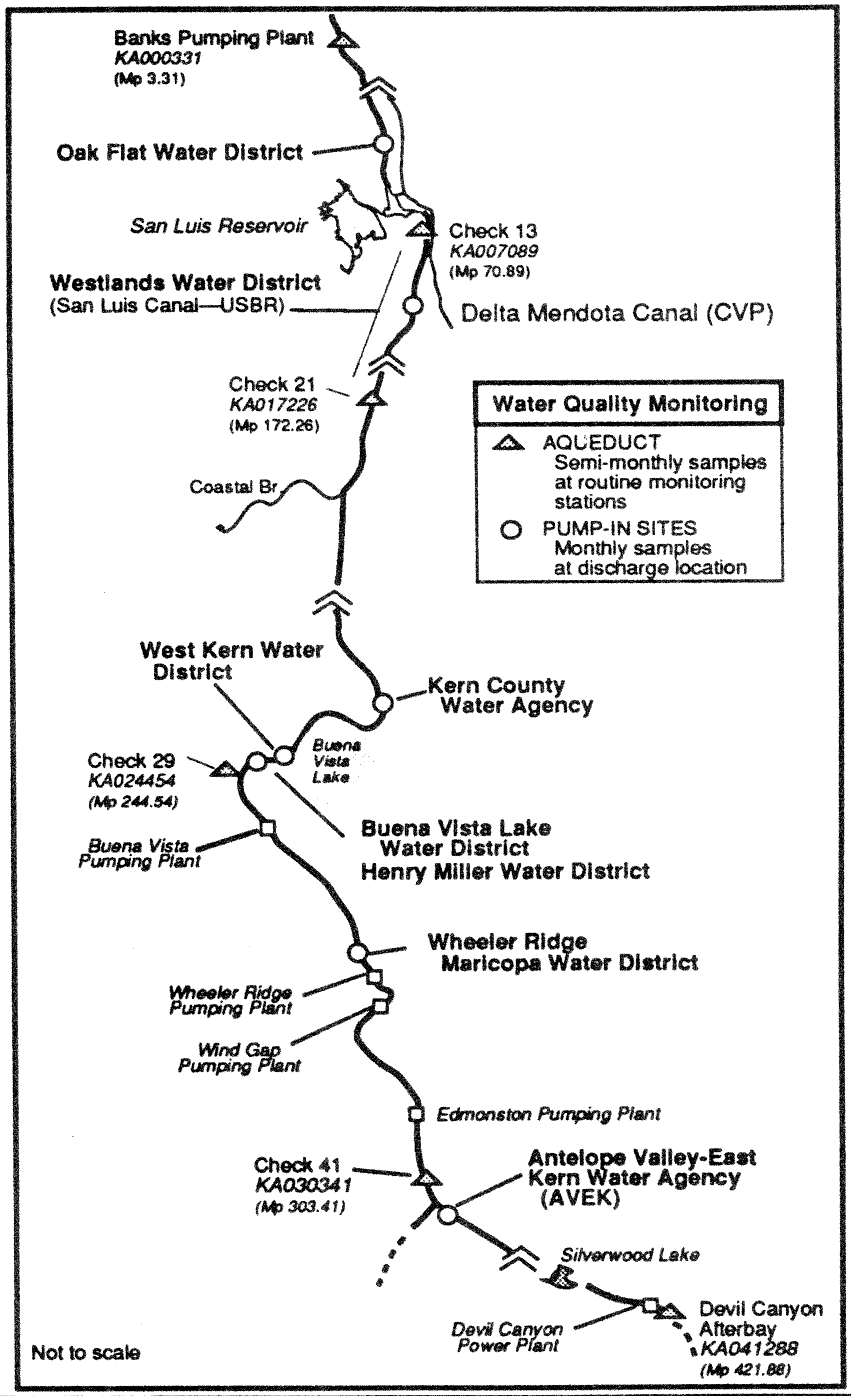
The recent drought from 1987 to 1992 caused the Central Valley Project CVP and State Water Project SWP to reduce allocations to federal and state contractors, respectively. Pump-ins, the term used to define ground water that is pumped from wells into the Aqueduct, were allowed to mitigate for the extreme water supply deficiencies imposed on water contractors. The CVP and SWP accepted well water in the Aqueduct and wheeled or granted credit to their water users for future use as a means of managing and distributing scarce water supply.

Acceptance of Non-Project water into SWP facilities was allowed provided its acceptance did not result in the significant degradation of SWP water quality, toxicity to fish and wildlife, or adverse changes in the suitability of the water for its beneficial uses, including municipal, industrial, agricultural or recreational purposes. Department of Water Resources DWR established water quality criteria for inorganic and organic chemicals and radioactivity for water accepted into the Aqueduct. Routine monthly and bimonthly sampling was established to monitor pump-in and Aqueduct water quality.

This report focuses on the effects of non-project ground water pump-ins on State Water Project water quality during 1989 to 1992. The three main topics addressed in the report were as follows: 1. Volumes of pump-ins were presented and compared to Aqueduct flows; 2. Pump-in concentrations of arsenic, selenium, chloride, sulfate, total dissolved solids, and specific conductance were discussed. The values were compared to Aqueduct water quality and to DWR criteria and Department of Health Services DHS drinking water standards; and 3. Aqueduct water quality at locations upstream and downstream of pump-ins was summarized and changes in water quality from pump-ins were discussed.

Inflow Volumes of Pump-ins

Non-project pumping into the State Water Project began on a small scale in 1990 with the United States Bureau of Reclamation USBR and the DWR accepting water into the San Luis Canal. The volume of water entering the Aqueduct from non-project pump-ins increased from about 5,000 acre-feet in 1990 to more than 155,000 acre-feet in 1992. The pump-in program contributed more than 300,000 acre-feet to the California Aqueduct from 1990 to 1992. A map with the locations of pump-ins is shown below.



In the Aqueduct between Banks Pumping Plant and Check 13, one pump-in was operated during January and February 1992 by Oak Flat Water District. The volume of 128 acre-feet accounted for less than 1% of total volume contributed by pump-ins.

Westlands Water District pump-ins, located in the San Luis Canal between Check 13 and Check 21, contributed the largest volume to the pump-in program. Pump-ins to the San Luis Canal began in June 1990 and totaled 5027 acre-feet for the year. The volume pumped into the San Luis Canal increased in 1991 to more than 82,000 acre-feet or about 50% of total annual pump-in. The volume increased again in 1992 to 128,000 acre-feet and accounted for more than 80% of the total pump-in volume that year.

Inflows to the Aqueduct from pump-ins contributed 8 to 9 percent of the Check 21 outflow in 1991 and 1992. During that period, monthly pump-ins accounted for as much as 45 percent of Check 21 outflows. Pump-ins contributed a similar percentage of the outflows at Edmonston Pumping Plant in 1991 (10.2%) and decreased to about 3.5% in 1992.

Kern County Water Agency, West Kern Water District, and Henry Miller Water District operated pump-ins located between Check 21 and Check 29. These three agencies made up the second largest water volume pumped into the Aqueduct. In 1991, total pump-in volume was more than 71,000 acre-feet (41% of total annual for all pump-ins). In 1992, the volume decreased to less than 20,000 acre-feet or about 12% of the annual total of pump-ins.

Wheeler Ridge-Maricopa Water Storage District had active pump-ins from February 1991 to December 1992. These pump-ins, located between Check 29 and Check 41, totaled about 16,000 acre-feet. Downstream of Check 41, Antelope-Valley East Kern Water District AVEK participated in the program from May 1991 to January 1992. Pump-in volume totaled about 12,000 acre-feet or less than 4% of the pump-in total in 1991 and 1992.

Water Quality of Pump-ins

In the Aqueduct between Banks Pumping Plant and Check 13, one pump-in located at mile post 35.22 had levels of nitrate and selenium that exceeded DWR Policy Criteria. Other constituents including chloride, total dissolved solids (TDS), sulfate, and specific conductance were higher than Aqueduct values (Table 1). This pump-in was shut down in February 1992 because of its poor water quality.

Pump-ins to the San Luis Canal had levels of arsenic, TDS, sulfate, and specific conductance that were much higher than Aqueduct values. [1] In addition, the pump-ins had higher levels of selenium than Aqueduct water. [2]

More than 35% of pump-in samples in the San Luis Canal portion of the Aqueduct had arsenic concentrations greater than 0.005 mg/l and about 15% of the samples had arsenic levels greater than 0.010 mg/l. While these concentrations were higher than Aqueduct values, pump-in arsenic levels were considerably lower than the DWR Policy Criterion and present maximum contaminant level MCL of 0.050 mg/l. The reporting levels (lowest concentration reported by the analytical laboratory) were different in 1991 and 1992. The laboratory had a reporting level of 0.002 mg/l in 1991 while the laboratory used in 1992 had a reporting level for arsenic of 0.005 mg/l. The higher reporting level used in 1992 was higher than ambient arsenic concentrations usually found in the Aqueduct.

Most pump-ins to the San Luis Canal had high sulfate concentrations. More than 90% of the samples had sulfate values that were twice as high as the maximum concentrations in the Aqueduct at Check 13. Sulfate levels in 10% and 18% of pump-in samples from 1991 and 1992, respectively, were higher than the DWR criterion of 600 mg/l. In addition, TDS and specific conductance values were much higher than Aqueduct levels. TDS levels in more than 90% of the pump-in samples were higher than Aqueduct values.

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[1] Much higher — 75% of the pump-in samples had values higher than the Aqueduct maximum at Check 13.
[2] Higher — 50 -75% of the pump-in samples had values higher than the Aqueduct maximum at Check 13.

Table 1
Summary of Pump-in Water Quality

	California Aqueduct	San Luis Canal	California Aqueduct		
	Banks PP to Ck 13	Check 13 to Check 21	Check 21 to Check 29	Check 29 to Check 41	Downstream of Check 41
Pump-in period					
1990	—	Jun - Dec	—	—	—
1991	—	Jan - Dec	Mar - Dec	Feb - Dec	May - Dec
1992	Jan - Feb	Jan - Dec	Jan - Dec †	Jan - Dec ¥	—
Total (acre-feet)	128	216214	91537	16256	11966
Arsenic	Equal / None	Much higher / Higher	Higher / Higher	Higher / None	Much higher / None
Selenium	Much higher / None	Higher / None	Equal / None	Equal / None	Lower / None
Nitrate	Much higher / None	Equal / None	Lower / None	Lower / None	Much higher / None
Chloride	Much higher / None	Lower / None	Lower / None	Lower / None	Lower / None
TDS	Much higher / None	Much higher / Much higher	Equal / None	Much higher / None	Lower / None
Sulfate	Much higher / None	Much higher / Much higher	Lower / None	Much higher / None	Lower / None
Specific conductance	Much higher / None	Much higher / Much higher	Equal / None	Much higher / None	Lower / None

† Except Mar, Jun, Jul, Aug, and Oct
¥ Except Aug

LEGEND	
Pump-ins	**Aqueduct**
Pump-ins compared to upstream Aqueduct value	Downstream change in constituent value
Lower : More than 75% of pump-in samples had values *lower* than the maximum Aqueduct level during months of active pump-ins .	**Lower**: Mean annual Aqueduct values were lower downstream of pump-ins.
Equal: 25-50% of pump-in samples had *higher* values than the Aqueduct maximum.	**None**: No detectable change in Aqueduct values downstream of pump-ins.
Higher: 50-75% of pump-in samples had *higher* values than the Aqueduct maximum.	**Higher**: Monthly or annual mean Aqueduct values were higher downstream of pump-ins.
Much higher: More than 75% of pump-in samples had *higher* values than the Aqueduct maximum.	**Much higher**: Mean Aqueduct values were significantly higher downstream of pump-ins.

Water quality of pump-ins located downstream of Check 21 was generally better than pump-ins in the San Luis Canal portion of the Aqueduct. Arsenic concentrations were high in many of the pump-ins located below Check 13 (Table 1). Between Checks 21 and 29, arsenic was high during April to July 1991 when levels exceeded the maximum contaminant level MCL and DWR Policy Criterion. Pump-ins below this section (Checks 29 to 41) also had high arsenic concentrations with more than 50% of the samples higher than 0.005 mg/l. In this portion of the Aqueduct, pump-ins had TDS, sulfate, and specific conductance values much higher than Aqueduct levels.

Pump-ins located downstream of Check 41 also had high arsenic concentrations. The mean arsenic level of pump-ins below Check 41 (0.012 mg/l) was higher than the *maximum* Aqueduct concentration of 0.006 mg/l at Check 41. These pump-ins had mean nitrate concentrations that were about three times higher than Aqueduct values.

While many pump-in samples had higher values of arsenic, selenium, TDS, sulfate, nitrate and specific conductance than the Aqueduct, some of the pump-ins had lower values than the Aqueduct. From Check 21 to 29, pump-in concentrations of selenium, chloride, and sulfate were about equal to or lower than Aqueduct values. Chloride and nitrate were low in pump-ins located between Checks 29 and 41. AVEK pump-ins (below Check 41) had low levels of selenium, chloride, TDS, sulfate, and specific conductance.

Effects on Aqueduct Water Quality

In the San Luis Canal, concentrations of arsenic, TDS, sulfate, and specific conductance values were significantly higher downstream at Check 21 than above the pump-ins at Check 13.

In 1989 and 1990, before heavy pump-ins, arsenic concentrations did not change from Check 13 to Check 21. During 1991 and 1992 pump-ins, monthly arsenic values at Check 21 were 0.001 mg/l higher than Check 13 in 33% of the samples. In addition, about 50% of the pump-in samples in 1991 had arsenic values of 0.004 mg/l or higher, while mean arsenic at Check 13 in 1991 was 0.002 mg/l.

Values of TDS, sulfate, and specific conductance increased in the San Luis Canal. For example in 1991, mean annual sulfate increased by 36 mg/l from Check 13 to Check 21. The change was even greater in 1992 when more water was pumped into the Aqueduct. Mean annual sulfate nearly doubled, increasing from 54 mg/l at Check 13 to 103 mg/l at Check 21.

Aqueduct concentrations of arsenic also increased between Check 21 and Check 29 at Buena Vista Lakes outflow. The greatest change in arsenic concentrations in the Aqueduct occurred from March to April 1991 when it increased from 0.002 to 0.018 mg/l. After the high April arsenic concentration, Aqueduct levels decreased to 0.003 mg/l by July 1991.

While some pump-in constituents were lower than the Aqueduct, there were no instances where Aqueduct water quality was improved by pump-ins. AVEK pump-ins, located below Check 41, had lower levels of selenium, chloride, TDS, sulfate, and specific conductance than the Aqueduct. Sulfate concentrations in 1991 and 1992 were lower down Aqueduct of the AVEK pump-ins. At the Devil Canyon Power Plant (mile post 412.88), mean sulfate values were about 20 mg/l lower than those upstream at Check 41 (mile post 303.41). The lower sulfate values at Devil Canyon Power Plant do not appear to be the result of pump-ins since AVEK pump-ins were active from May to December 1991 and did not operate in 1992. Sulfate values at Devil Canyon were not significantly different in 1991 (with pump-ins) than 1992 (without pump-ins).

Downstream of Check 29 there were no detectable changes in Aqueduct water quality because of the pump-in program. In general, the pump-in volumes below Check 29 were too low to affect Aqueduct water quality although levels of some constituents were much higher than Aqueduct values.

Introduction

This report is a follow-up to the previous report, **A Preliminary Analysis of Water Quality Impacts from Ground Water Pump-In on the State Water Project** (DWR 1991a). That report examined summer data (June, July, August, and September) for the three year period, 1989 to 1991.

Non-project ground water pumping into the State Water Project began in 1990 on a small scale with the United States Bureau of Reclamation USBR and the Department of Water Resources DWR accepting water into the San Luis Canal. The program was established to assist State and federal Water Contractors during periods of entitlement deficiency caused by the California drought.

The discussion is organized by sections of the aqueduct as follows: Banks Pumping Plant to Check 13, Check 13 to Check 21 (San Luis Canal), Check 21 to Check 29, Check 29 to Check 41, and Check 41 to Devil Canyon Afterbay. In addition, monthly aqueduct data is presented at seven stations from 1989 to 1992.

More than 15 water quality constituents were routinely monitored in the aqueduct and at pump-in sites. The discussion in this report is limited to the following: arsenic, selenium, nitrate, chloride, sulfate, total dissolved solids TDS, and specific conductance. These constituents were deemed to have a potential effect on aqueduct water quality.

The Department of Water Resources policy document, **DWR Policy on Acceptance of Non-Project Ground Water Inflow to the State Water Project During Period of Entitlement Deficiency** (Appendix B) outlines specific provisions for acceptance of non-project water into the SWP. One of the main provisions is that non-project water does not result in significant degradation of SWP water quality. Non-project water must meet the current Department of Health Services DHS primary drinking water standards for inorganic and organic chemicals and radioactivity.

For the constituents discussed in this report, a summary of the DWR Pump-in Policy Water Quality Criteria as well as DHS and USEPA Drinking Water Standards is presented in Table 2. A complete list of constituents covered in the DWR Policy document is presented in Appendix B.

Table 2
Water Quality Standards and DWR Pump-in Criteria

Constituent	Units	DWR Pump-in Policy Criteria	DHS Drinking Water Standards	EPA Drinking Water Standards
Primary				
Arsenic	mg/l	0.05	0.05	0.05
Selenium	mg/l	0.01	0.01	0.05
Secondary				
Nitrate (as NO_3)	mg/l	45	45	10 (as N)
Chloride	mg/l	600	250 / 500 / 600 [a]	250
Total Dissolved Solids	mg/l	1500	500 / 1000 / 1500 [a]	500
Sulfate	mg/l	600	250 / 500 / 600 [a]	250
Specific conductance	µS/cm	2200	900 / 1600 / 2200 [a]	—

[a] *Recommended / Upper / Short term maximum*

Part 1

Methods

This section identifies the sampling locations of pump-ins and Aqueduct stations. Analytical methods used for chemical analyses as well as quality assurance and control techniques are also addressed in this section.

San Luis Canal (USBR)

Samples were collected by the USBR between June 1991 and December 1992 in the San Luis Canal. Pump-ins and Aqueduct waters were analyzed in 1991 and 1992 following USEPA methodology (Table 3). In addition to those constituents shown, boron, fluoride, and manganese were routinely tested for but the results are not discussed in this report. Table 4 lists the location and frequency of Aqueduct and pump-in sites sampled. Samples were collected monthly during summer and semi-monthly during the remainder of the year. To characterize the influence of non-project pump-ins on the Aqueduct, one station was located upstream of the Westlands pump-ins at Milepost 104.19, six stations were sampled within the section of inflows, and one station at Check 21 (Milepost 172.40) was located below the pump-ins.

Samples from June 1991 through March 1992 were analyzed by BSK Analytical Labs while FGL Environmental Analytical Chemists conducted the analysis between April and December 1992. Data was provided on computer disk by the USBR, Fresno Office.

Table 3
Water Quality Analysis Methods

Constituent	Units	California Aqueduct: Department of Water Resources Bryte Laboratory — Method*	MDL†	Reporting Level	Precision RPD‡ of duplicates	Accuracy§ (% Recovery)	San Luis Canal: BSK Analytical Labs — Method*	Reporting Level	San Luis Canal: FGL Environmental Analytical Chemists — Method*	Reporting Level
Inorganics										
Arsenic	mg l^{-1}	206.3	0.0002	0.001	0.020	77 - 121	7061	0.002	206.2	0.005
Selenium	mg l^{-1}	270.3	0.0002	0.001	0.020	74 - 121	7741	0.002	270.2	0.005
Nitrate	mg l^{-1}	353.2	0.02	2.0	4.3	78 - 118	352.2	1	353.2	0.5
Minerals										
Chloride	mg l^{-1}	325.2	0.2	1	2.6	89 - 114	325.2	1	325.2	1
Hardness	mg l^{-1}	2340B	—	1	—	—	200.7	1	—	—
Sodium	mg l^{-1}	273.1	0.2	1	2.3	82 - 116	6010	0.1	—	—
Sulfate	mg l^{-1}	375.2	0.36	1	3.5	82 - 120	375.2	2	375.4	1
TDS	mg l^{-1}	160.1	0.4	1	12	—	160.1	5	160.1	40
Other										
Specific conductance	µS cm^{-1}	120.1	1	5	2	—	9050	1	120.1	1

* USEPA Methodology or Standard Methods
† Method Detection Limit
‡ RPD = Relative Percent Difference
§ Surrogate Recovery Range

Table 4
Location of Pump-in Sites and Sampling Frequency in the San Luis Canal (Check 13 to Check 21)

No.	Description	Milepost	Pool	1991							1992											
				J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	Upstream	**104.19**	15				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1	Sano #1	105.00L												x		x		x		x	x	
2	Sano #2	105.21L												x		x		x		x	x	
3	Sano #3	105.60L												x		x		x		x	x	
4	Costa	107.10R		x		x	x			x					x	x		x		x	x	
5	Panoche Creek	107.63R												x			x		x	x	x	
	Check 15	**108.46R**							x	x	x	x	x	x	x	x	x	x	x	x	x	x
6	G. Pruett	108.85L	16				x	x			x			x		x		x		x	x	
7	Fundus 22 Harness	110.49L						x		x				x			x			x	x	
8	Fundus 22N	110.49L						b		b										b	b	
9	Panoche Creek Siphon	111.90								x	x	x	x	x	x		x	x	x	x	x	x
10	C. Pruett	111.91R		x		x	x							x		x		x		x	x	
11	Gramis	113.65R					x	x	x	x												
12	Panoche 14-2	114.00R					x	x	x	x			x						x	x		
13	Panoche 16 Tellas	114.00R					b	b	b	b												
14	Panoche 16-2E	114.00R					b	b	b	b			b									
15	Gowens	115.00L						x		x			x				x				x	
16	Lateral 7	115.43L		x			x				x		x	x	x		x		x	x	x	
17	Robertson 22N	116.91R					x	x		x			x						x		x	
18	Robertson 22S	116.91R					b	b		b			b						b		b	
19	Panoche SW 25	118.49R				x	x	x		x			x			x		x		x		x
20	Panoche NW 31	118.49R				b	b	b		x						b		b		b		b
21	Panoche S 36	119.56R				x	x	x		x									x			
22	Britz	120.80L				x	x	x		x			x			x		x		x	x	
23	Lateral 10L Guenther	121.92L																	x		x	
	Check 16	**122.05R**							x	x	x	x	x	x	x	x	x	x	x	x	x	x
24	Cardella	122.59RA	17				x	x			x		x						x		x	
25	Three Rocks Well #1	123.89R								x					x		x		x	x	x	
26	Three Rocks Well #2	123.89R								b					b		b		b	b		
27	California Coastal	124.16RB						x														
28	Gragnani	127.40L		x			x	x		x			x	x							x	x
29	Hyland	128.49R								x												
30	T. Nunes	130.81R							x	x												
31	San Andreas 13-1NE	132.77L									x					x		x		x	x	
32	San Andreas 13-3NW	132.77L									b					b		b		b	b	
33	Lateral 16 Clausen	132.81L													x			x			x	
	Check 17	**132.94R**							x	x	x	x	x	x	x	x	x	x	x	x	x	x
34	LAN 18-7SW	133.80L	18													x	x	x		x	x	
35	LAN 18-7SE	133.80L														b	b	b		b	b	
36	Lat.17L Saviez	133.81L																x		x	x	
37	Vista Verdi	133.81R						x	x	x	x			x		x		x		x	x	
38	Tres Picos Well #23B	133.81R						b	b	b	b			b		b		b		b	b	
39	Tres Picos Well #23C	133.81R						b	b	b	b			b		b		b		b	b	
40	Tres Pic 26 A	135.48RA				x	x	x	x	x				x				x		x	x	
41	Tres Pic 26 C	135.48RB					x	x	x					x		x		x		x	x	
42	Tres Pic 36 A	136.00R																				
43	Five Points GW18-1.0S	136.03L				x	x	x		x				x		x		x		x	x	
44	Five Points GW19-1.0S	136.03L				b	b	b		b				b		b		b		b	b	
45	Lat.20L BTO #25	137.11L									x			x				x			x	
46	CMA/ G&J	137.31L					x	x		x				x		x				x	x	
47	CMA/ 5 pts	137.83L					x	x		x	x			x			x	x		x	x	
48	Burford	138.24L					x	x		x					x	x				x	x	
49	V&A Goldenrod	139.40L		x					x	x				x						x	x	
50	Burford	140.55LA		x			x	x		x				x		x				x	x	
51	Harris # 13A	140.55LB									x									x	x	
52	Graham	141.02R				x	x	x		x					x	x			x		x	
53	Harris # 29H	142.58R						x			x				x		x		x	x	x	
54	Harris # 27H	143.00L				x	x	x		x				x		x				x	x	
55	Coalinga Canal	143.16R					x	x	x	x			x			x	x		x	x		
56	Harris 34H	143.21R					x	x		x												
	Check 18	**143.21R**							x	x	x	x	x	x	x		x	x	x	x	x	x

x — Sample collected b —blended samples Aqueduct sampling stations shown in **bold**

Table 4 (continued)

No.	Description	Milepost	Pool	1991 J	J	A	S	O	N	D	1992 J	F	M	A	M	J	J	A	S	O	N	D
57	Harris # 14A	144.25L	19																	x	x	
58	Lat. 26L BRO #24	147.02L																			x	
59	D & G W/7-3	147.75RC					x	x		x				x				x		x	x	
60	Cinqo W/20-4	147.75RC					b	b		b				b				b			b	
61	Lat.27L SLO	149.12L									x											
62	Lat.27L Walker	149.12L												x							x	x
63	Anderson V #2	152.75L		x		x	x	x		x				x						x	x	
64	Highway 198	152.76X									x	x	x	x	x		x	x	x	x	x	x
65	Marr #74	153.10R		x				x		x										x	x	
66	Marr #3	154.10L		x	x					x				x				x			x	
67	Anderson III #1	155.15L		x		x	x	x	x		x					x					x	
	Check 19	**155.63X**							x	x	x	x	x	x	x	x	x	x	x	x	x	x
68	Lone Star Well 1	156.37LA	20	x		x		x		x				x		x					x	
69	Lone Star Well 2	156.37LB		x		x	x	x		x												x
70	Lat. 31L Waymire	156.40L												x							x	
71	CVLC 12-3	157.41R																			x	x
72	CVLC 23-2	157.40L																			x	
73	Lat. 32L Waymir	158.47L														x		x		x	x	
74	Lat.33L MFT #27	160.45L						x	x	x	x				x			x		x	x	
75	Lat.33L MFT #26	160.45L						b	b	b	b				b			b		b		
76	Half Moon Produce	160.50L		x		x	x	x		x				x		x		x		x		x
77	CVLC #34-4	160.50RA																			x	
78	CVLC #35-4	160.50RB																			x	
79	L.Woolf #144	160.50RC																				x
80	Lat.34L Stone #12	161.50L					x	x							x					x	x	
81	Lat.34L Stone #21	161.50L					b	b							b					x	b	
82	Donaghy #5-1	161.60L		x		x	x	x		x								x		x	x	
83	Lat.35L W.Schuh #9	162.60L				x		x			x					x		x		x		x
84	Lat.35L W.Schuh #22	162.60L						x		x						x						x
85	Lat. 35L WFT #24	162.60L						x		x						x		x			x	
86	Green	163.20R		x		x	x	x			x			x		x		x		x	x	
87	Lat.36L Err #15-1	163.69L				x	x	x		x										x	x	
88	Lat.36L Err #15-2	163.69L				x					x							x				x
89	Lat.36L Err #16-1	163.69L				x		x		x												x
90	Kochergen # 18-1	164.11R		x		x	x	x		x				x		x		x		x	x	
91	Kochergen # 24-3	164.11R		b		b	b	b		b				b		b		b		b	b	
92	Kochergen # 24-5	164.11R		b		b	b	b		b				b		b		b		b	b	
93	Kochergen # 18-4	164.63R				x	x	x		x				x		x		x		x	x	
	Check 20	**164.68R**							x	x	x	x	x	x	x		x	x	x	x	x	x
94	Lat.37L Err #15-2	167.04L	21				x	x		x								x				
95	Lat.37L Don #23-1	167.04L				x	x	x		x						x					x	
96	Lat.37L Don #23-2	167.04L				x	x	x		b						b				x		x
97	Chavarri Farm Co.	167.86RA		x		x	x	x	x	x				x		x		x			x	
98	Rod-West/ Valley View	167.86RB							x					x								
99	D & M Chavarria	167.86RC						x						x		x						
100	Lat.38L Don #36-1	169.30L							x	x												x
101	Couture #5	169.37R		x		x				x						x		x		x	x	
102	Jones #1	169.88L				x	x			x										x		x
103	Jones #2	169.88L								b										b		b
104	Couture # 6	170.83R		x		x							x									
105	K-Farmin 12-1	171.50LA		x		x		x		x							x	x			x	
106	Couture # 8	171.50LB					x	x		x												
	Check 21	**172.58**					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

x — sample collected b — blended samples Aqueduct sampling stations shown in **bold**

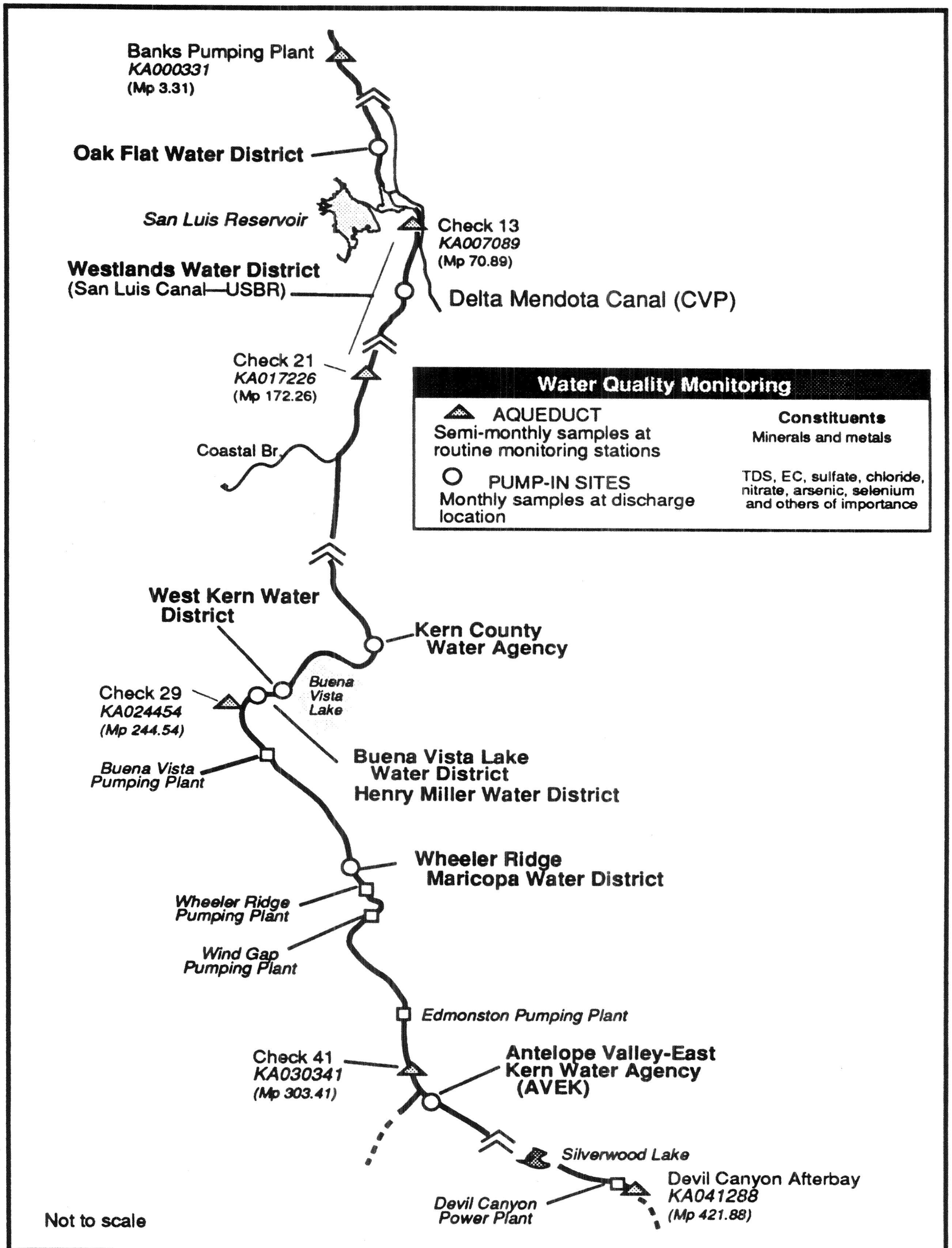
California Aqueduct (DWR)

Field sampling methods used by DWR are described in the **SWP Water Quality Manual** (DWR, 1991b). Monthly Aqueduct samples were collected from January 1989 to December 1992 from below the water surface with either a Kemmerer or Van Dorn sampler. Pump-in samples were taken at the discharge pipe, prior to entering the Aqueduct. Arsenic, selenium, and sodium samples were filtered and preserved with nitric acid (HNO_3). Sulfate, chloride, total dissolved solids, and nitrate samples were filtered. Samples were transported in ice chests to DWR's Bryte Chemical Laboratory in West Sacramento within 24 hours of collection. Hardness was calculated from calcium and magnesium following the method described in Standard Methods (APHA, 1991).

Six Aqueduct stations monitored by DWR are discussed. A more comprehensive discussion of water quality at State Water Project stations can be found in **State Water Project Water Quality, 1989 to 1991** (DWR, 1992). The stations addressed here are Banks Pumping Plant (Milepost 3.31), Check 13 (Milepost 70.89), Check 21 (Milepost 172.26), Check 29 (Milepost 244.54), Check 41 (Milepost 303.41) and Devil Canyon Afterbay (Milepost 412.88).

Figure 1

Map showing the non-project pump-ins and Aqueduct sampling sites



Quality Assurance and Quality Control

Field

Field blank water was prepared at Bryte Laboratory from deionized water that met ASTM specifications for Type 1 reagent grade water. The field crews transported the blank water to the field and processed the water through the sampler in the same manner as an Aqueduct or inflow sample. The field blank sample was handled just as the field sample. For each sampling day two field blank samples were collected; one was filtered and fixed with HNO_3, the other was fixed with acid.

Laboratory

As required for laboratory accreditation in California, Bryte Chemical Laboratory has filed a Quality Assurance Plan with the Department of Health Services. The Plan must cover items required by the USEPA, such as organization and responsibility, laboratory samples procedures and identification, analytical methods, internal quality control, and corrective action. Internal quality control checks includes duplicates, spikes, check standards, reference standards, and control charts.

A summary of quality control data for DWR's Bryte Laboratory is presented in Table 3. The table shows reporting level, precision, and accuracy (% recovery) for the constituents discussed in this report.

Documentation and Reporting

Data reports provided by the three analytical laboratories (DWR's Bryte Laboratory, BSK Analytical Labs, and FGL Environmental Analytical Chemists) used different terms to describe low level analyte concentrations. The terms used were reporting level (DWR and BSK) and MDL = method detection limit (FGL Analytical). Table 3 presents a list of reporting values for the three laboratories. The terms are defined as follows :

Method Detection Limit — the lowest concentration of an analyte that can be determined statistically in a sample or blank at 99% confidence level.

Reporting Level — a concentration that is 3 standard deviations higher than the MDL. The actual value is 2 to about 10 times higher than the method detection level. The risk of a false negative (ß error) becomes acceptably low.

Descriptive statistics such as mean and standard deviation were calculated for concentrations less than the reporting level or MDL by assuming the value was equal to the reporting level or MDL. Other approaches used to report analyte concentrations lower than the reporting level are to assume that all nondetectable points are equal to zero, assume nondetectable points are equal to half the detection limit, or use log-probit analysis (Travis and Land, 1990).

Part 2
Inflow Volumes of Pump-ins

This section provides data on volumes of non-project inflow into the Aqueduct during 1990 to 1992. Also presented are monthly Aqueduct flows at Check 21 and Edmonston Pumping Plant in order to characterize the contribution of pump-in water to the Aqueduct flows.

Banks Pumping Plant to Check 13

One pump-in, operated by the Oak Flat Water District, participated in the pump-in program during January and February 1992. A total of 128 acre-feet was pumped into the Aqueduct from one well during the two month period (Table 5). The pump-in was shut down by March 1992 due to high concentrations of selenium and nitrate.

Check 13 to Check 21 (San Luis Canal)

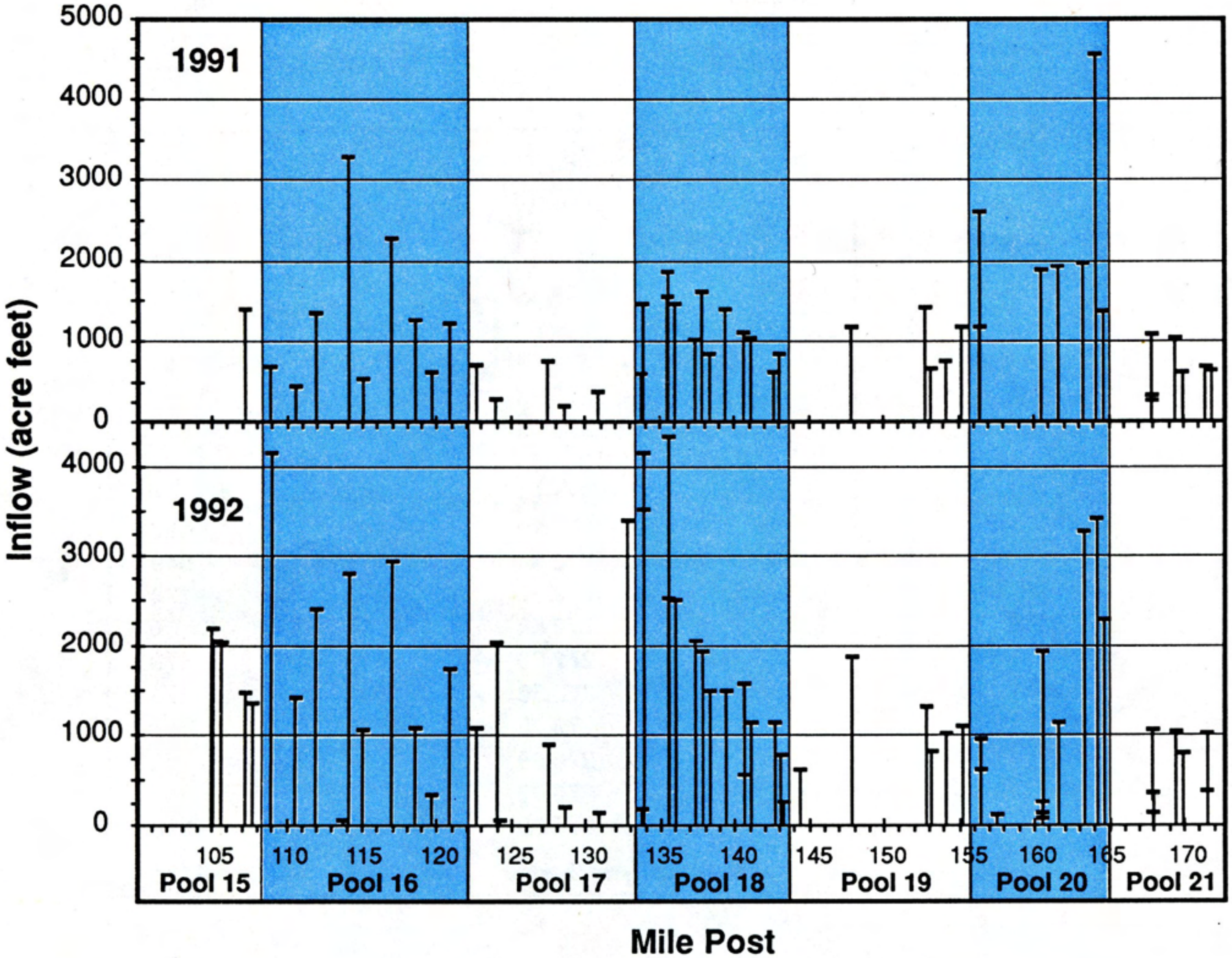
The volume of water contributed by Westlands Water District pump-ins was greater than all other Aqueduct pump-ins combined from 1990 to 1992. In 1991, a total of more than 82,000 acre-feet was pumped into the Aqueduct which accounted for nearly 50 % of the total Aqueduct pump-ins. In 1992, the total volume increased to 128,000 acre-feet and more than 80 % of the total of all pump-ins.

Pump-ins to the San Luis Canal began in June 1990 when a total of 86 acre-feet was accepted. Monthly inflows from July through December 1990 ranged from 679 to 1152 acre-feet for an annual total of 5027 acre-feet (Table 5). In 1991, the volume of water entering the San Luis Canal via pump-ins ranged from 908 to 9320 acre–feet per month. Additional inflows from the Mendota Pool (Lateral 7) increased the average monthly volumes by 1200 to 5700 acre-feet.

A greater number of pump-ins were active during 1992 (Table 4). The number of pump-ins sampled at least twice was 57 in 1991 and 70 in 1992 (exclusive of initial samples). Total annual inflow of 128,620 acre-feet in 1992 was about 46,000 acre-feet higher than in 1991. Inflows were greater than 14,000 acre-feet in January, September, October, November, and December (Table 5). Mean monthly inflows from pump-ins in 1992 were greater than 10,000 acre-feet.

Table 5
Monthly Pump-in Volumes (acre-feet) from 1990 to 1992

Field Division Location		*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*TOTAL*
Delta	*1990*	0	0	0	0	0	0	0	0	0	0	0	0	0
Banks Pump.	*1991*	0	0	0	0	0	0	0	0	0	0	0	0	0
Plant to	*1992*	9	119	0	0	0	0	0	0	0	0	0	0	128
Check 13	*Total*	9	119	0	0	0	0	0	0	0	0	0	0	**128**
San Luis	*1990*	0	0	0	0	0	86	713	724	679	698	1152	975	5027
Check 13	*1991*	958	908	1155	3008	5306	5141	6266	8914	11841	12261	11979	14830	82567
to	*1992*	14598	6715	1423	7041	10674	7341	8879	9786	14286	17048	16241	14588	128620
Check 21	*Total*	15556	7623	2578	10049	15980	12568	15858	19424	26806	30007	29372	30393	**216214**
San Joaquin	*1990*	0	0	0	0	0	0	0	0	0	0	0	0	
Check 21	*1991*	0	0	2402	9811	13458	8378	1402	3176	8112	9392	7529	8887	72547
to	*1992*	4966	3768	0	1243	2367	0	0	0	1480	0	1242	3924	18990
Check 29	*Total*	4966	3768	2402	11054	15825	8378	1402	3176	9592	9392	8771	12811	**91537**
Check 29	*1990*	0	0	0	0	0	0	0	0	0	0	0	0	0
to	*1991*	0	15	581	1060	1224	1012	964	1357	895	1213	565	239	9125
Check 41	*1992*	343	543	1205	1197	196	218	317	0	1006	510	422	1174	7131
	Total	343	558	1786	2257	1420	1230	1281	1357	1901	1723	987	1413	**16256**
Southern	*1990*	0	0	0	0	0	0	0	0	0	0	0	0	0
Check 41	*1991*	0	0	0	0	275	1331	1541	1673	1519	1664	1562	1645	11210
to	*1992*	756	0	0	0	0	0	0	0	0	0	0	0	756
Devil Canyon Afterbay	*Total*	756	0	0	0	275	1331	1541	1673	1519	1664	1562	1645	**11966**
Totals	*1990*	0	0	0	0	0	86	713	724	679	698	1152	975	**5027**
	1991	958	923	4138	13879	20263	15862	10173	15120	22367	24530	21635	25601	**175449**
	1992	20672	11145	2628	9481	13237	7559	9196	9786	16772	17558	17905	19686	**155625**
Total 1990-1992														**336101**



In 1991, pump-ins to the San Luis Canal were measured at 48 locations (Figure 2). Nearly half of the pump-ins had annual flows of 1000 to 2000 acre-feet. Four pump-ins contributed more than 2000 acre-feet for the year. In contrast to 1991, eighteen pump-ins were greater than 2000 acre-feet in 1992. Of the 61 inflows measured in 1992, about 70 percent were 2000 acre-feet or less.

Table 6
Annual Pump-in Volumes by Milepost
from Check 21 to Check 41

	Milepost	1991	1992
Check 21	238.00	31280	10899
to	240.20	3320	1176
Check 29	242.65	37947	6915
Total		72547	18990
Check 29	266.91	0	82
to	267.46	666	831
Check 41	267.64	61	0
	268.15	532	227
	268.15		962
	269.66	1224	0
	270.24	178	57
	270.24		0
	270.24	757	291
	270.24		1437
	271.21	708	0
	272.10	408	693
	272.30	312	549
	272.39	263	124
	272.58	1084	0
	272.80	895	470
	273.59	591	371
	273.75	1223	0
	276.09		72
	276.09		587
	277.20	223	378
Total		9125	7131

Check 21 to Check 29

The three pump-in sites within the San Joaquin Field Division from Check 21 to Check 29 accounted for the second highest volume of water pumped into the Aqueduct. The Cross Valley Canal pump-in operated by Kern County Water Agency, is located at milepost 238.00. Pump-ins located at mileposts 240.20 and 242.65 were operated by West Kern Water District and Henry Miller Water District, respectively. In 1991, a total of more than 72,000 acre-feet (41 % of the total Aqueduct pump-in) was pumped into the Aqueduct from these three sites (Table 6). The volume declined in 1992 to less than 20,000 acre-feet or about 12 % of the pump-in total.

Check 29 to
Check 41

Pump-ins operated by the Wheeler Ridge-Maricopa Water Storage District were located from milepost 266.91 to 277.20 (Table 6). In 1991, a total of 9125 acre-feet was pumped in the Aqueduct. The total volume in 1992 declined to 7131 acre-feet. These pump-ins made up a small (less than 5 %) proportion of the total pumped in to the Aqueduct in 1991 and 1992

Check 41 to
Devil Canyon Afterbay

Pump-in volumes from the Antelope-Valley East Kern Water District AVEK were also low compared to those from San Luis Canal and the Aqueduct between Check 21 and Check 29 (Table 5). AVEK participated in the program from May 1991 to January 1992 and total inflow for that period was 11966 acre-feet (4 % of the total Aqueduct pump-in).

Well Inflows Compared to Aqueduct Flows

Inflows from ground water pump-ins contributed a sizable proportion of the total Aqueduct flow during 1991 and 1992 (Table 7). For example in 1991, the annual contribution from ground water pump-ins accounted for about 8 percent of the Check 21 outflow. Monthly outflows at Check 21 ranged from about 7,000 to 155,000 acre-feet in 1991. On a monthly basis, pump-ins accounted for 1 to 30 percent of the Check 21 outflow during 1991. Pump-ins contributed the greatest proportion of Check 21 outflow in April (30.0%), and September (21.3%).

In 1992, pump-ins comprised 9.5 percent of the Check 21 outflow. The monthly ratio of pump-in volume to Check 21 outflow was highest in February (45.87%), January (24.66%), November (23.02%), and December (20.10%). Monthly Check 21 outflow in 1992 ranged from 14,638 (February) to 243,579 (June) acre-feet. Pump-ins made up more than 10 percent of the Check 21 outflow for 6 months each year (1991 and 1992).

In the San Joaquin Field Division, inflows to the Aqueduct from pump-ins comprised 10.2% of the 1991 outflow at Edmonston Pumping Plant (EPP) and decreased to and 3.5 % in 1992. During April 1991, nearly the entire flow at EPP was composed of water from pump-ins. In 1991, pump-ins also made up more than 20 percent of the outflow volume at EPP during March (38.19%), May (20.76%), and September (19.63%). During 1991, outflows at EPP ranged from 7,810 to 111,574 acre-feet.

Total ground water inflows from pump-ins between Check 21 and Check 41 decreased from 81,672 acre-feet in 1991 to 26,121 acre-feet in 1992. Total outflow at EPP was similar during 1991 and 1992. The 1992 monthly contribution of EPP outflow made up from pump-ins was greater than 10 percent during February (32.74%) and March (12.23 %).

Table 7
Monthly Pump-in Volumes and Aqueduct Flows (acre-feet), 1989 to 1992

Milepost		Aqueduct 70.89 Check 13 Outflow	Pump-ins Check 13 to Check21	Aqueduct 172.26 Check 21 Outflow	Pump-ins Percent of Check 21 outflow	Pump-ins Check 21 to Check 41	Aqueduct 293.45 Edmonston Pumping Plant	Pump-ins Percent of Edmonston PP outflow
1989	Jan	228,316		117,192			72,391	
	Feb	295,322		135,910			29,061	
	Mar	212,216		171,013			74,775	
	Apr	351,908		258,403			149,099	
	May	368,661		249,890			119,673	
	Jun	608,848		386,484			102,960	
	Jul	640,246		409,338			106,637	
	Aug	471,151		337,357			96,411	
	Sep	279,547		255,817			149,874	
	Oct	249,128		232,122			154,323	
	Nov	253,883		222,681			152,694	
	Dec	199,780		149,720			99,087	
Total		***4,159,006***		***2,925,927***			***1,306,985***	
1990	Jan	255,598		141,214			105,552	
	Feb	357,087		231,940			144,728	
	Mar	328,037		267,816			161,456	
	Apr	283,737		220,490			136,667	
	May	322,709		226,680			115,322	
	Jun	463,370	86	298,566	0.03		115,057	
	Jul	568,697	713	393,612	0.18		145,412	
	Aug	393,275	724	315,782	0.23		163,669	
	Sep	217,785	679	206,616	0.33		161,871	
	Oct	209,278	698	200,856	0.35		158,384	
	Nov	163,675	1,152	155,024	0.74		121,066	
	Dec	137,259	975	124,957	0.78		86,390	
Total		***3,700,507***	***5,027***	***2,783,553***	***0.18***		***1,615,574***	
1991	Jan	111,711	958	92,419	1.04		82,851	
	Feb	88,873	908	59,207	1.53	15	46,377	0.03
	Mar	22,131	1,155	6,908	16.72	2983	7,810	38.19
	Apr	29,335	3,008	10,044	29.95	10871	11,430	95.11
	May	135,965	5,306	85,656	6.19	14682	70,727	20.76
	Jun	270,633	5,141	154,696	3.32	9390	111,574	8.42
	Jul	274,984	6,266	153,725	4.08	2366	79,496	2.98
	Aug	182,096	8,914	120,890	7.37	4533	79,619	5.69
	Sep	58,158	11,841	55,478	21.34	9007	45,893	19.63
	Oct	93,083	12,261	94,362	12.99	10605	78,902	13.44
	Nov	79,690	11,979	80,709	14.84	8094	77,919	10.39
	Dec	109,827	14,830	111,586	13.29	9126	108,239	8.43
Total		***1,456,486***	***82,567***	***1,025,680***	***8.05***	***81,672***	***800,837***	***10.20***
1992	Jan	56,678	14,598	59,190	24.66	5309	58,411	9.09
	Feb	16,150	6,715	14,638	45.87	4311	13,168	32.74
	Mar	54,767	1,423	31,854	4.47	1205	9,850	12.23
	Apr	118,116	7,041	87,178	8.08	2440	38,574	6.33
	May	244,401	10,674	175,922	6.07	2563	104,791	2.45
	Jun	376,394	7,341	243,579	3.01	218	93,899	0.23
	Jul	345,713	8,879	221,998	4.00	317	72,073	0.44
	Aug	260,323	9,786	172,204	5.68	0	73,193	0.00
	Sep	112,400	14,286	104,238	13.71	2486	82,650	3.01
	Oct	104,815	17,048	100,305	17.00	510	81,417	0.63
	Nov	68,415	16,241	70,555	23.02	1664	58,678	2.84
	Dec	68,943	14,588	72,577	20.10	5098	65,499	7.78
Total		***1,827,115***	***128,620***	***1,354,238***	***9.50***	***26,121***	***752,203***	***3.47***

Part 3

Water Quality of Pump-Ins

The discussion of pump-in water quality is divided by Aqueduct section. The results of water quality analyses are presented with emphasis on constituent levels in comparison with the DWR Pump-in Policy criteria. Constituent levels in the Aqueduct are also presented for comparison with pump-in constituent values.

Banks Pumping Plant to Check 13 (mile post 3.03 to 70.89)

Oak Flat Water District participated in the pump-in program during January and February 1992. One pump-in location, located at mile post 35.22, pumped a total of 128 acre-feet during the two months of operation (Table 8).

Nitrate and selenium levels were high at this pump-in and both constituents exceeded the DWR Policy Criteria of 45 and 0.010 mg/l, respectively (Table 8). Arsenic levels were low with all samples equal to or less than 0.001 mg/l. Chloride concentrations were about twice as high as levels present at Banks Pumping Plant. Total dissolved solids, sulfate, and specific conductance were also higher than values found at Banks Pumping Plant. The pump-in was shut down in February 1992 because of the high levels of nitrate and selenium.

Table 8
Water Quality of Non-Project Pump-ins — Banks Pumping Plant to Check 13

units = mg/l except specific conductance = µS/cm

TOC/DOC Br⁻	DWR Policy Criteria	Mean	Min	Max	n
Arsenic	0.050	0.001	<0.001	0.001	5
Selenium	0.010	0.012	0.010	0.015	9
Nitrate	45	57	48	70	5
Chloride	600	298	262	336	5
TDS	1500	925	801	1060	5
Sulfate	600	146	87	196	5
Specific conductance	2200	1626	1440	1840	5

Check 13 to Check 21 (San Luis Canal)

(mile post 70.89 to 172.26)

The non-project pump-in program in the San Luis Canal was administered by the USBR. Samples were collected from June 1990 to December 1992 from pump-ins and at eight locations in the Aqueduct. Pump-ins from Westlands Water District were analyzed by two analytical laboratories; BSK Analytical Labs (June 1991 to March 1992) and FGL Environmental Analytical Chemists (April to December 1992).

Arsenic

Arsenic concentrations of ground water pump-ins in 1991 ranged from the reporting level of 0.002 mg/l to 0.032 mg/l. Of the 201 samples collected in 1991, about 83 % had arsenic values greater than or equal to 0.002 mg/l (Table 9). None of the samples taken in 1991 or 1992 exceeded either the current maximum contaminant level (MCL) or DWR Policy Criterion of 0.05 mg/l. However, more than 35 % of the samples had arsenic levels greater than or equal to 0.005 mg/l. Arsenic levels were greater than or equal to 0.01 mg/l in more than 15 % of the samples collected in 1991 and 1992.

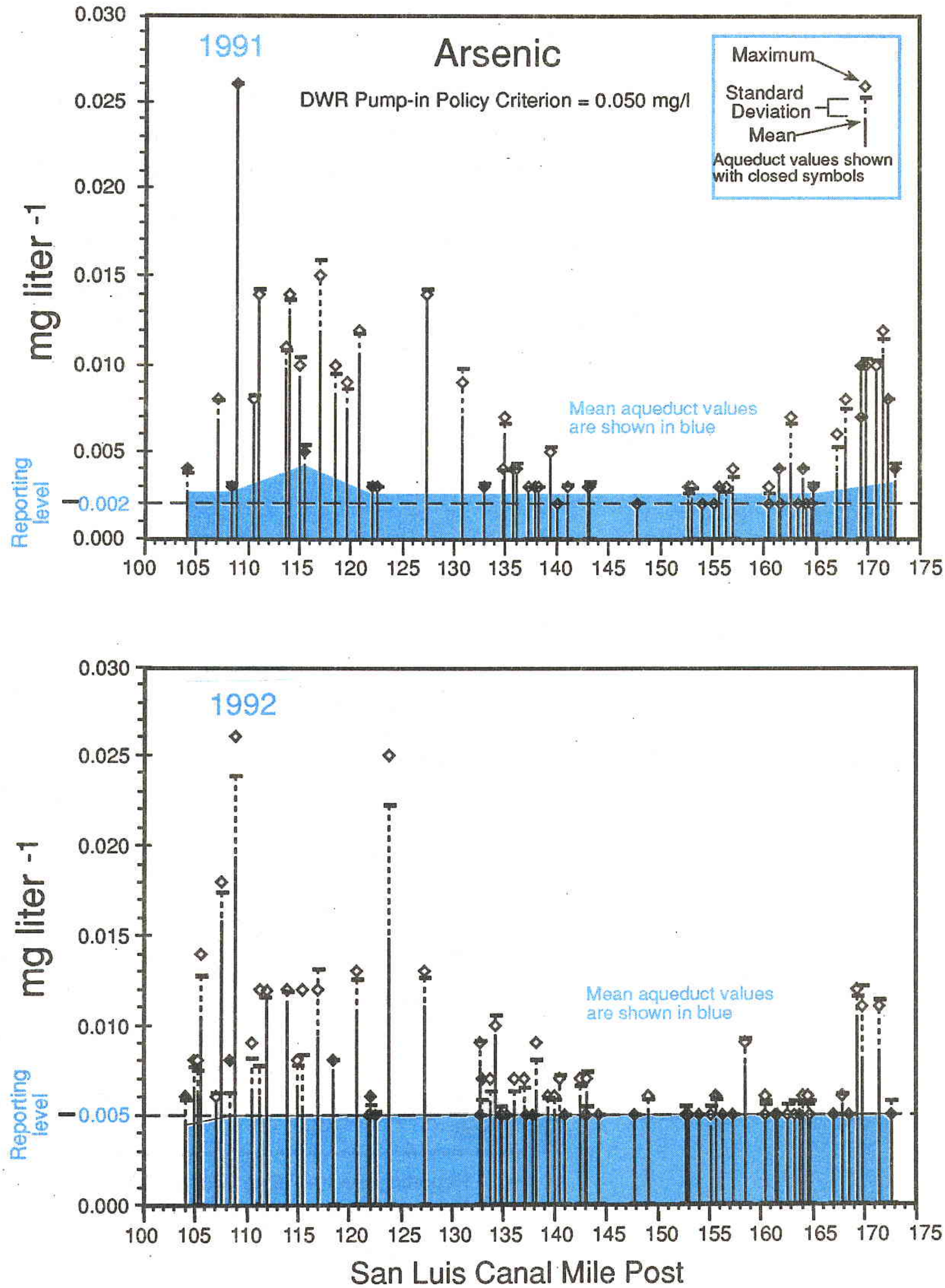
Data presented in Figure 3 shows the mean, maximum, and standard deviation for ground water inflows with a minimum of two samples collected annually. Each pump-in location is represented by a vertical line. Pump-ins sampled once do not appear on this figure. Mean annual arsenic values of ground water pump-ins were highest in pump-ins from about mile post (MP) 107 to 131. The mean arsenic value for all ground water pump-ins sampled in 1991 was 0.005 mg/l.

Table 9
Frequency of Arsenic Concentrations in San Luis Canal Pump-ins

Interval mg/l	1991 Number	1991 Percent	1992 Number	1992 Percent
< 0.002 [a]	34	16.9	*Below reporting level*	
≥0.002	167	83.1		
≥0.003	137	68.2		
≥0.004	102	50.7		
Total < 0.005 [b]	***119***	***59.2***	***192***	***64.6***
≥0.005	82	40.8	105	35.4
≥0.01	33	16.4	45	15.2
≥0.02	3	1.5	5	1.7
Total	***201***		***297***	

[a] Reporting level — June 1991 to February 1992
[b] Reporting level — March 1992 to December 1992

Figure 3
Arsenic concentrations of pump-ins and the San Luis Canal



Arsenic concentrations during 1992 were similar to 1991 with a mean value of 0.007 mg/l. The analytical method used from March to December 1992 had a higher reporting level (0.005 mg/l) than that used from June 1991 to February 1992 (0.002 mg/l). Direct comparison of the data at levels near the detection limits is therefore difficult. Of the 297 samples analyzed in 1992, about 65 % had arsenic levels less than 0.005 mg/l compared to about 60 % in 1991.

U.S. Environmental Protection Agency (USEPA) is evaluating the current MCL because recent health effects information reveal that there may be significant cancer concerns associated with arsenic. The new standard proposed by the USEPA is expected to be between 0.002 and 0.020 mg/l and probably around 0.005 mg/l (AWWA, 1993). Although MCL's are not enforceable in raw water supplies, many of the ground water pump-ins would exceed the new arsenic standard. For example if the new MCL was 0.005 mg/l, more than 35 % of the samples collected from Westlands Water District pump-ins in 1991 and 1992 would exceed the new MCL. The DWR policy for accepting pump-ins into the program is tied to MCL's for most constituents.

Selenium

The selenium analytical methods used from June 1991 to February 1992 produced a reporting level of 0.002 mg/l. Samples collected from March to December 1992 were analyzed by a different laboratory using a less sensitive analytical method that had a reporting level of 0.005 mg/l. DWR's Bryte Laboratory has a reporting level of 0.001 mg/l for selenium (see Methods Section).

In 1991, of the 205 ground water pump-in samples collected, about 68 % had selenium levels less than 0.002 mg/l and nearly 84 % of the samples were below 0.005 mg/l (Table 10). Of the remaining 33 samples, nine were at or above the MCL and DWR Policy Criterion of 0.010 mg/l. Pump-ins at the following mileposts had selenium concentrations in 1991 equal to or greater than 0.010 mg/l (the number of samples are shown in parenthesis): 160.45 (1), 163.20 (4), and 167.86 (4).

The frequency distribution of selenium concentrations was similar in 1992 with about 88 % of the samples less than 0.005 mg/l.
Seven samples exceeded the MCL and DWR Policy Criterion value of 0.01 mg/l. The federal drinking water standard was increased from 0.01 to 0.05 mg/l in July 1992 while the state MCL and DWR Pump-in Policy values did not increase.

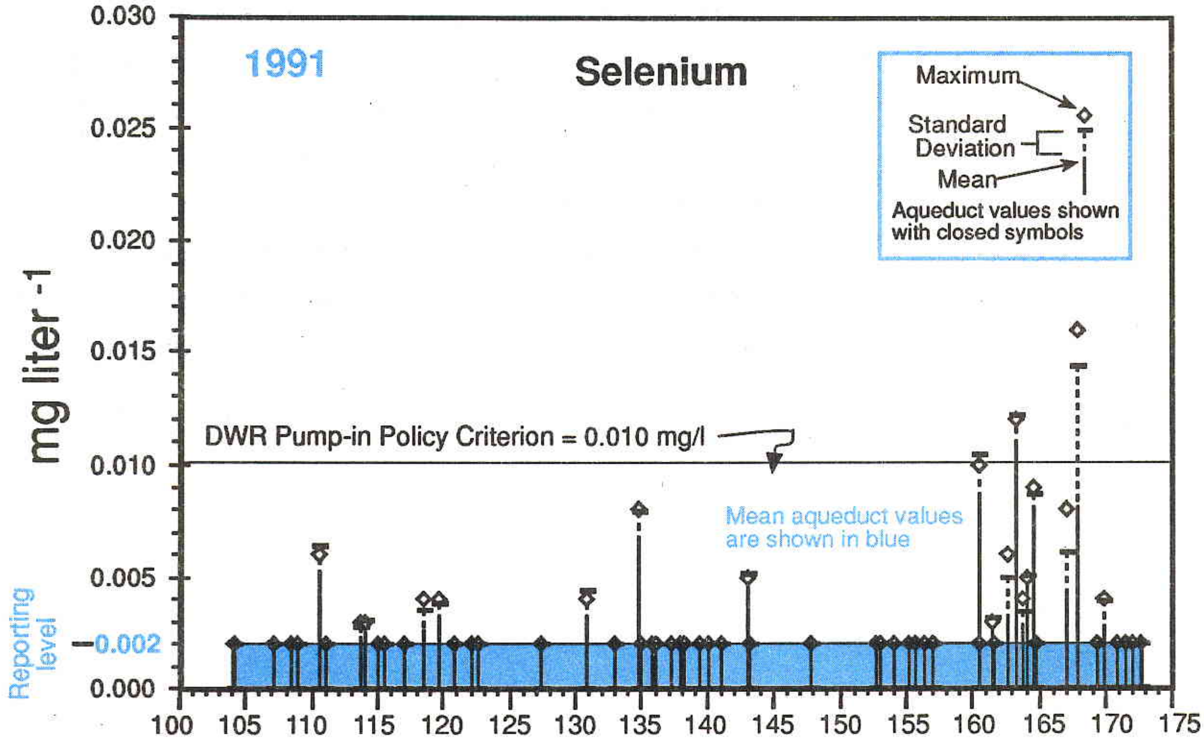
Table 10
Frequency of Selenium Concentrations in San Luis Canal Pump-ins

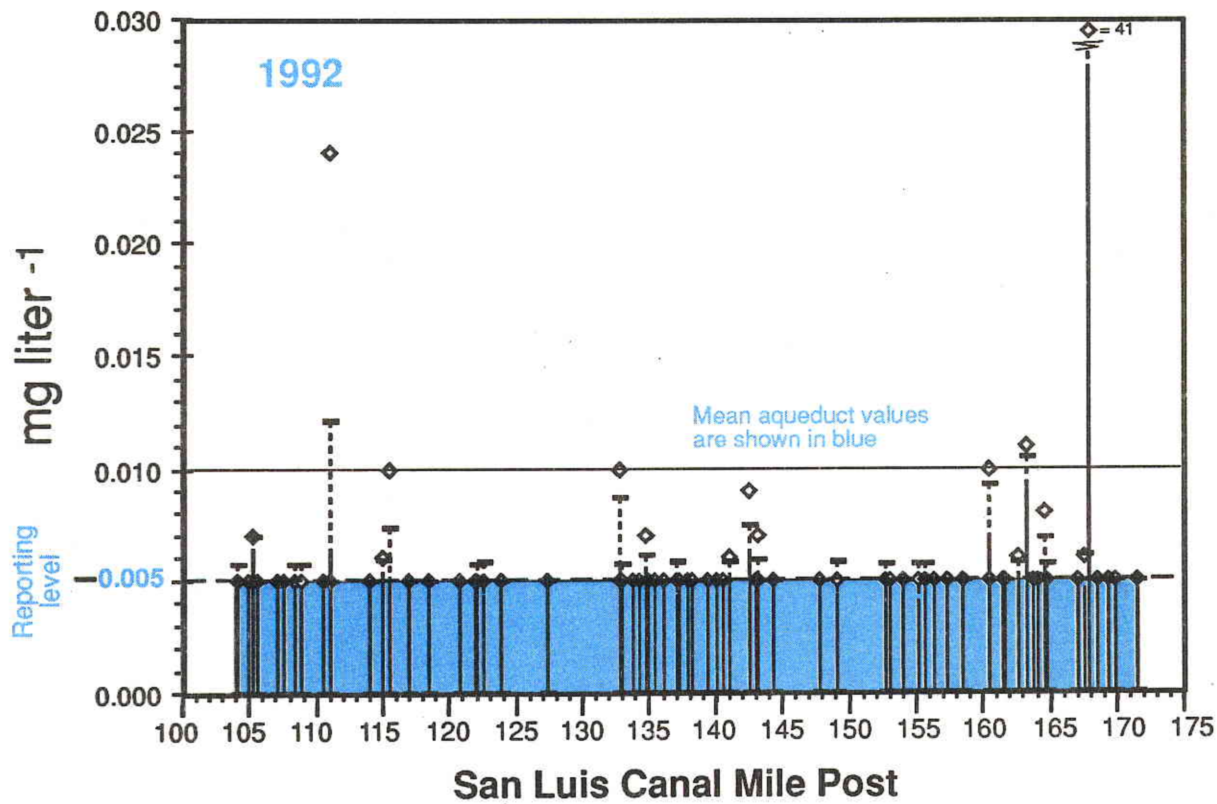
Interval mg/l	1991 Number	1991 Percent	1992 Number	1992 Percent
< 0.002 [a]	139	67.8		
≥0.002	65	31.7	*Below reporting level*	
≥0.003	56	27.3		
≥0.004	48	23.4		
Total < 0.005 [b]	***172***	***83.9***	***262***	***87.9***
≥0.005	33	16.1	36	12.1
≥0.01	9	4.4	7	2.3
≥0.02	1	0.5	2	0.7
Total	***205***		***298***	

[a] Reporting level — June 1991 to February 1992
[b] Reporting level — March 1992 to December 1992

Data presented in Figure 4 shows the mean, maximum, and standard deviation of selenium in ground water pump-ins with a minimum of two samples collected each year. The mean values of samples collected in the Aqueduct are shown in the shaded area of the figures. Although Aqueduct values appear higher in 1992, the difference results from a less sensitive analytical method in 1992. Many of the higher selenium levels occurred at pump-ins located from about mile post 160 to 170 in 1991 and 1992. DWR selenium concentrations at Check 13 (MP 70.89) and Check 21 (MP 172.26) during 1989 to 1992 are presented in Table A-2.

Figure 4
Selenium concentrations of pump-ins and the San Luis Canal





Nitrate

Concentrations of nitrate found in non-project pump-ins ranged from less than 1 mg/l to about 50 mg/l. A large percentage of the samples had nitrate levels within the range normally present in the Aqueduct. In 1991, 51% of the samples had values less than or equal to 1 mg/l compared to 45 % in 1992 (Table 11). Nitrate concentrations of non-project pump-ins were similar during 1991 (mean = 5.0) and 1992 (mean = 4.5).

During both years, about 75 % of the samples had nitrate concentrations less than or equal to 5 mg/l which is generally the upper range present in the Aqueduct. Fewer than 5 % of the samples had nitrate concentrations higher than 20 mg/l.

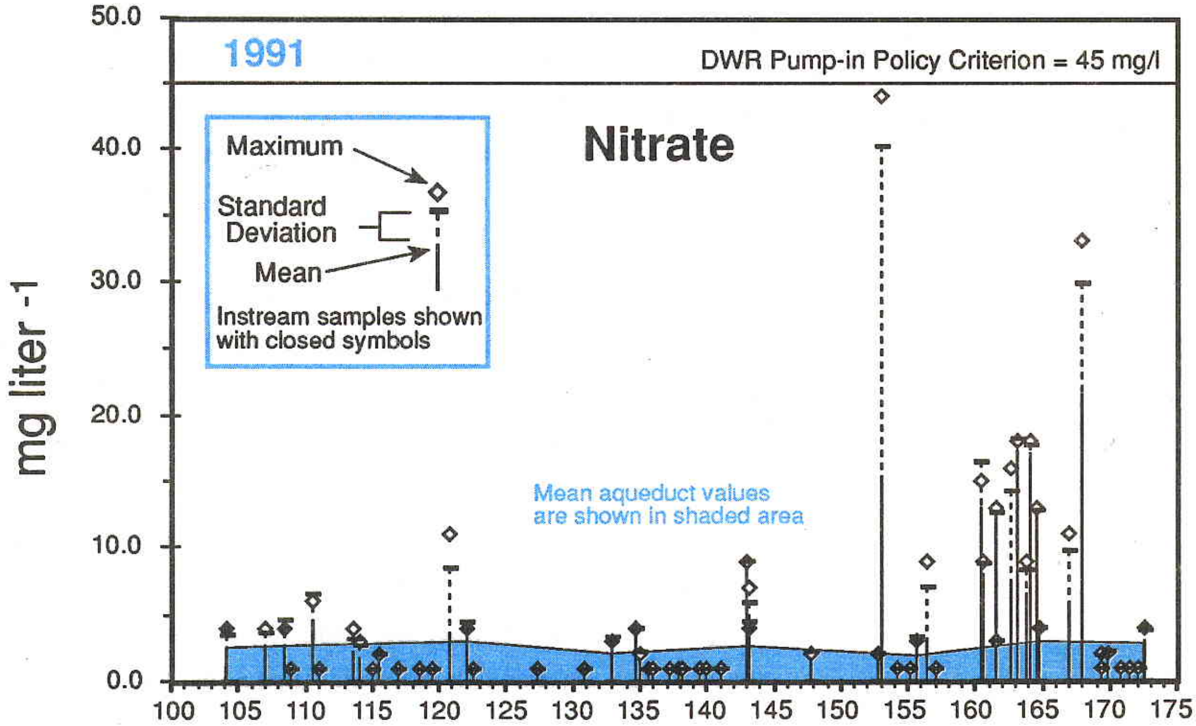
Data presented in Figure 5 shows the mean, maximum, and standard deviation of nitrate in ground water pump-ins with a minimum of two samples collected each year. The mean values of samples collected in the Aqueduct are shown in the shaded area of the figures.

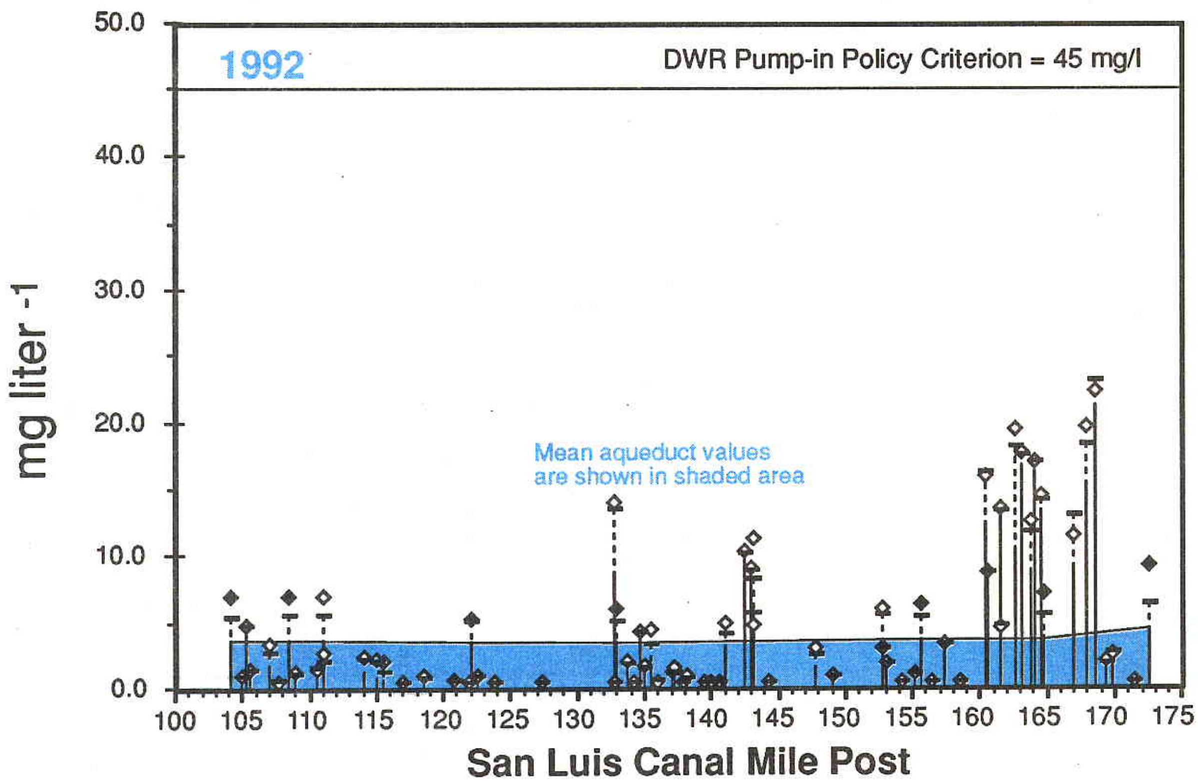
Table 11

Frequency of Nitrate Concentrations in San Luis Canal Pump-ins

Interval	1991		1992	
mg/l	Number	Percent	Number	Percent
< 0.5	*Not reported*		108	36.6
≤ 1	103	51.2	132	44.7
> 1	98	48.8	163	55.3
> 5	55	27.4	76	25.8
> 10	34	16.9	47	15.9
> 20	6	3.0	5	1.7
Total	*201*		*295*	

Figure 5
Nitrate concentrations of pump-ins and the San Luis Canal





Chloride

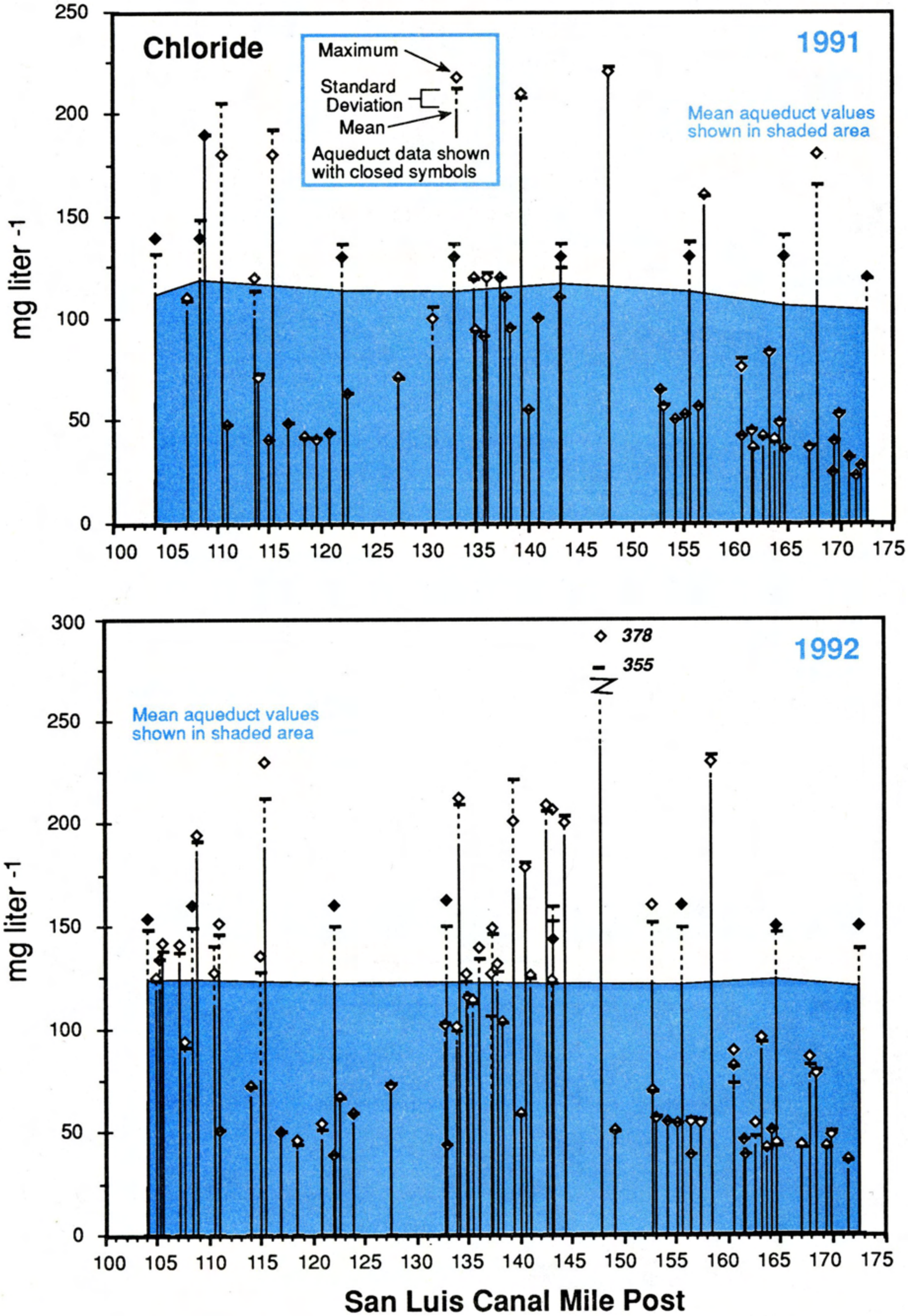
Levels of chloride in non-project pump-ins to the San Luis Canal ranged from less than 30 mg/l to 270 mg/l during 1991 and 1992. Chloride values of non-project pump-ins were higher in 1992 (mean = 94) than 1991 (mean = 74). In 1992, the chloride levels were fairly evenly distributed in intervals of less than 50 mg/l, 50 to 99 mg/l, and 100 to 150 mg/l with about 30 % of the samples in each category (Table 12). In 1991, about 40% of the samples had chloride concentrations less than 50 mg/l. There were few samples from either year with chloride concentrations greater than 200 mg/l.

Data presented in Figure 6 shows the mean, maximum, and standard deviation of chloride in ground water pump-ins with a minimum of two samples collected each year. The mean values of samples collected in the Aqueduct are shown in the shaded area of the figures. No samples exceeded the DWR Policy Criterion of 600 mg/l.

Table 12
Frequency of Chloride Concentrations in San Luis Canal Pump-ins

Interval	1991		1992	
mg/l	Number	Percent	Number	Percent
< 50	81	40.3	88	29.8
≥ 50	120	59.7	207	70.2
≥ 100	51	25.4	125	42.4
≥ 150	19	9.5	42	14.2
≥ 200	5	2.5	15	5.1
Total	*201*		*295*	

Figure 6
Chloride concentrations of pump-ins and the San Luis Canal



Sulfate

Sulfate concentrations of pump-ins were greater than Aqueduct values during 1991 (mean=450) and 1992 (mean=478). About 86 % of the samples had sulfate concentrations of 300 mg/l or higher during the two years (Table 13). Few non-project pump-in samples during 1991 or 1992 had sulfate levels in the range found in the Aqueduct at Check 13 (less than 75 mg/l). In fact, more than 90% of the samples had sulfate levels that were twice as high as maximum Check 13 concentrations.

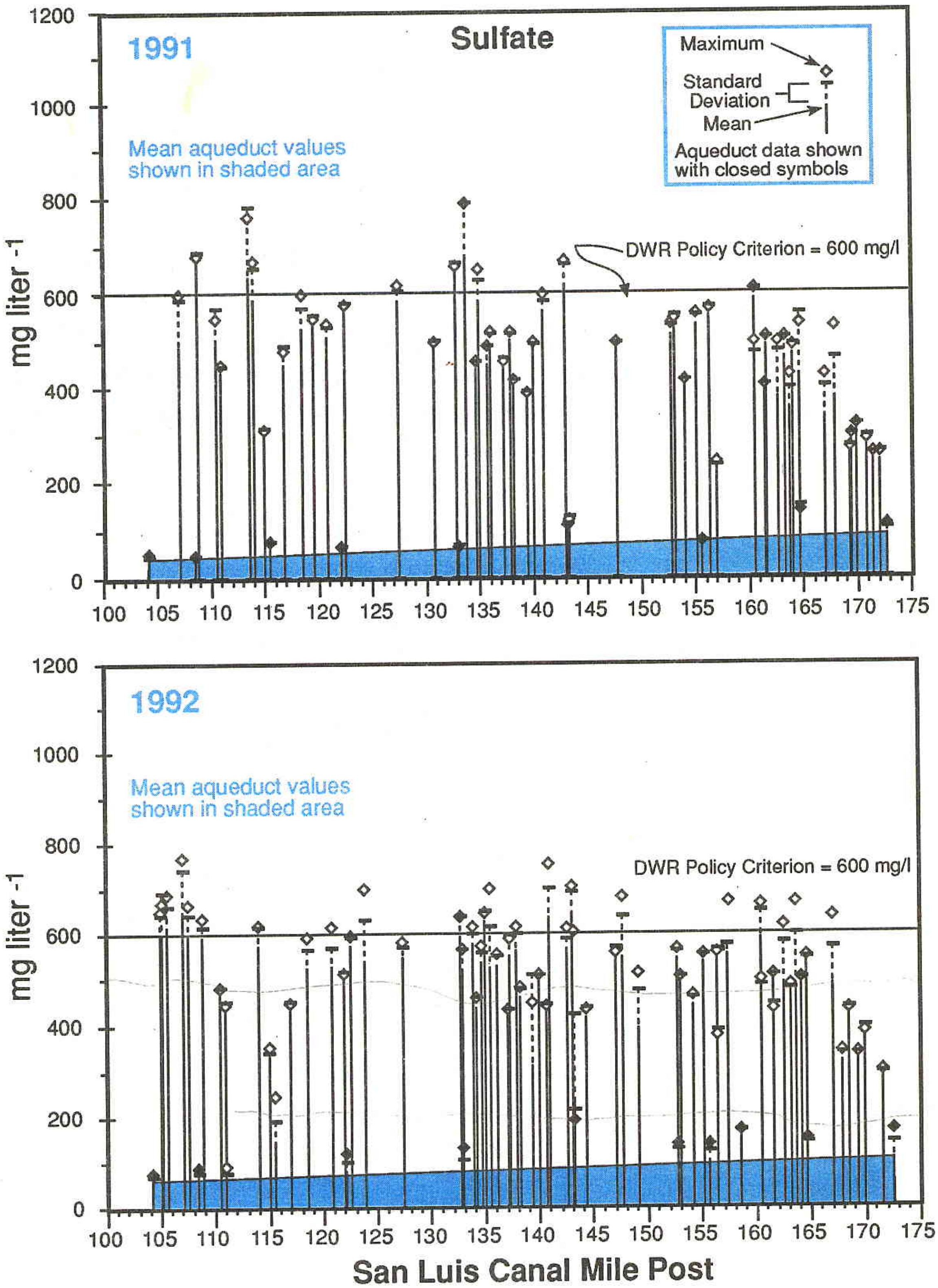
A number of samples had sulfate values greater than the DWR Policy Criterion level of 600 mg/l. In 1991 about 10 % of the samples had sulfate levels higher than 600 mg/l compared to 18 % in 1992. Pump-ins in this category that exceeded the DWR Policy Criterion were either shut down, blended with other wells or blended with Westlands District water to reduce sulfate below 600 mg/l.

Data presented in Figure 7 shows the mean, maximum, and standard deviation of sulfate in ground water pump-ins with a minimum of two samples collected each year. The mean values of samples collected in the Aqueduct are shown in the shaded area of the figures.

Table 13
Frequency of Sulfate Concentrations in the San Luis Canal Pump-ins

Interval	1991		1992	
mg/l	Number	Percent	Number	Percent
≥ 75	212	99.1	310	96.6
≥ 150	208	97.2	291	90.7
≥ 300	184	86.0	278	86.6
≥ 600	21	9.8	59	18.4
Total	***214***		***321***	

Figure 7
Sulfate concentrations of pump-ins and the San Luis Canal



Total Dissolved Solids (TDS)

Total dissolved solids were higher in non-project pump-ins than the San Luis Canal. TDS of all non-project pump-ins was similar for 1991 (mean = 873) and 1992 (mean = 879). While TDS levels in the Aqueduct were generally less than 500 mg/l, more than 90 % of the pump-ins exceeded that value (Table 14).

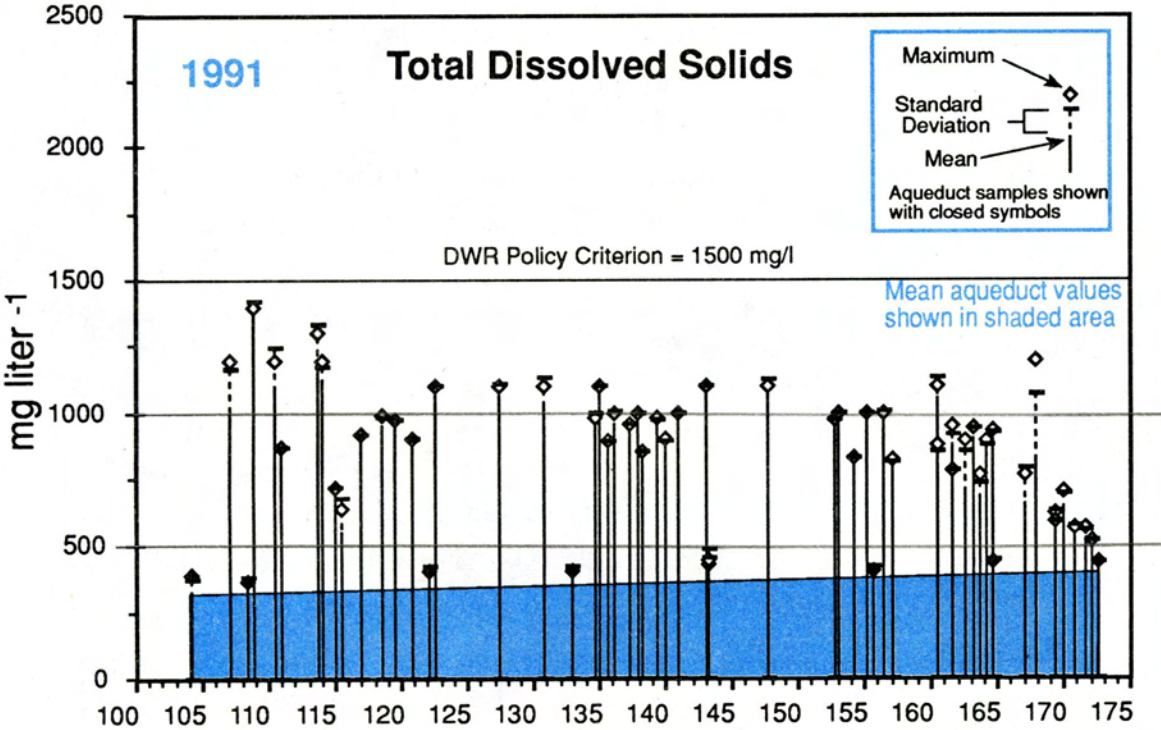
Most of the pump-ins in 1991 and 1992 had TDS values from 500 to 1000 mg/l. A greater percentage of samples had TDS values greater than 1000 mg/l in 1992 (31 %) than 1991 (16 %). One sample in 1992 had a TDS level greater than the DWR Policy Criterion of 1500 mg/l (Figure 8).

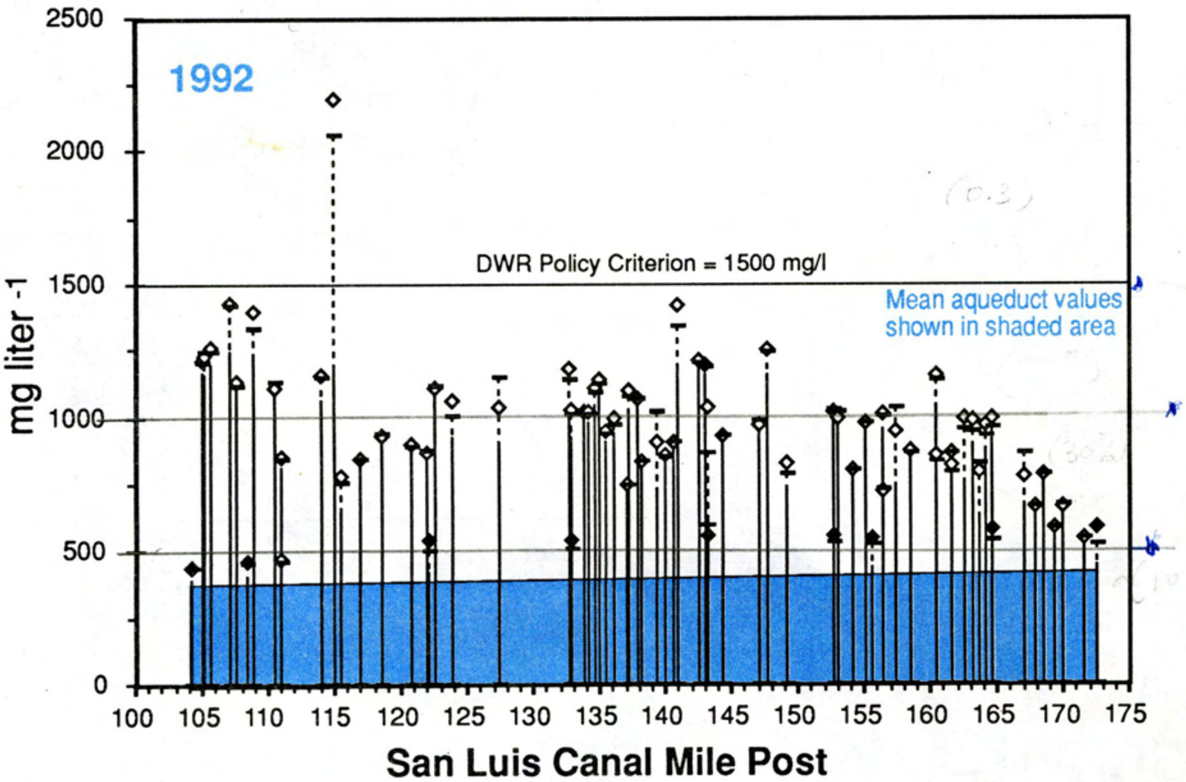
Data presented in Figure 8 shows the mean, maximum, and standard deviation of sulfate in ground water pump-ins with a minimum of two samples collected each year. The mean values of samples collected in the Aqueduct are shown in the shaded area of the figures.

Table 14
Frequency of Total Dissolved Solids in San Luis Canal Pump-ins

Interval	1991		1992	
mg/l	Number	Percent	Number	Percent
< 500	6	3.0	28	9.5
≥ 500	195	97.0	268	90.5
≥ 1000	33	16.4	92	31.1
≥ 1500	0	0	1	0.3
Total	*201*		*296*	

Figure 8
Total dissolved solids of pump-ins and the San Luis Canal





Specific Conductance

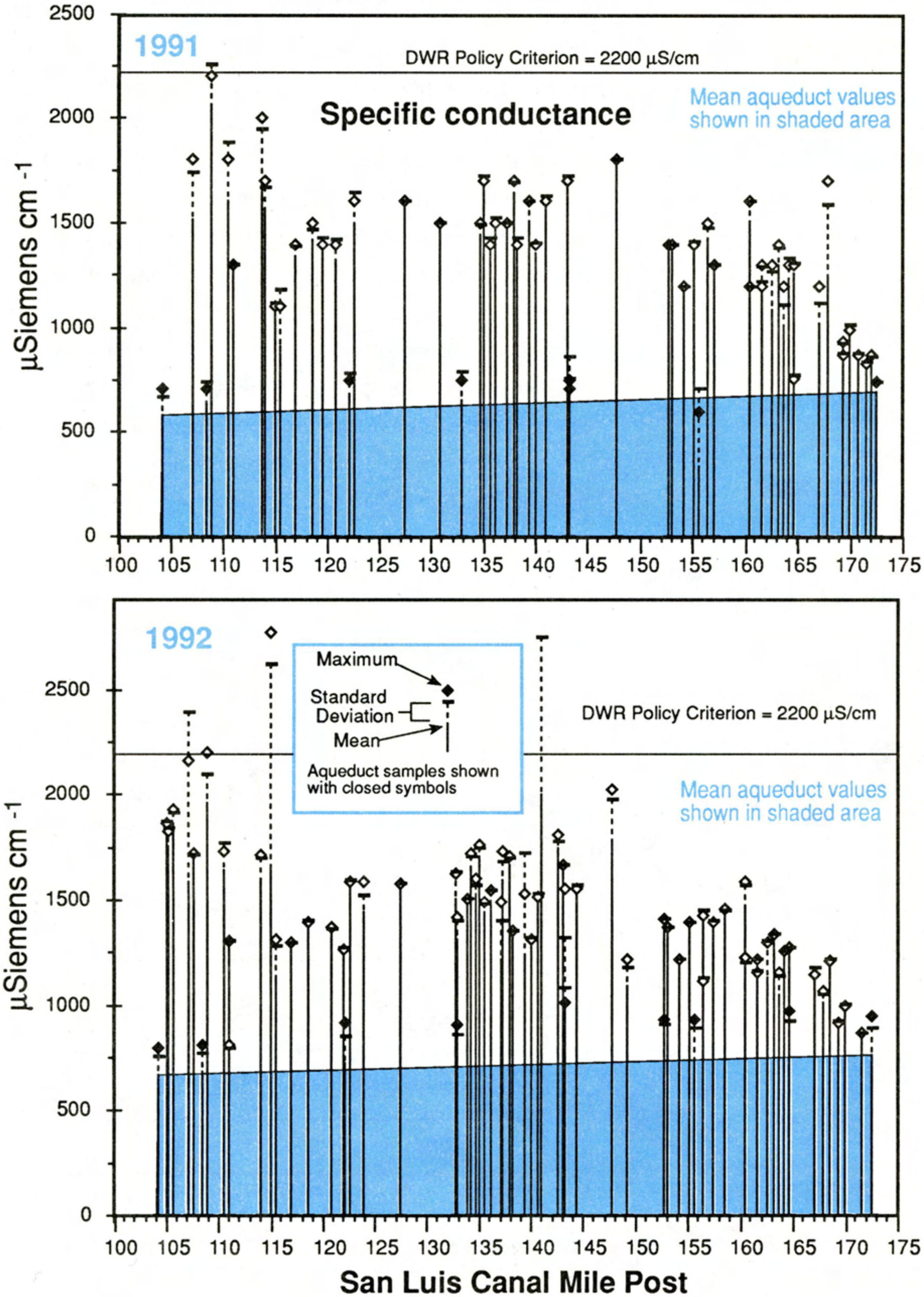
Non-project pump-ins had higher specific conductance values in 1991 (mean=1310) and 1992 (mean=1361) than the Aqueduct. While specific conductance was rarely greater than 1000 µS/cm in the Aqueduct, more than 80 % of the pump-ins exceeded that value (Table 15). A large proportion of the pump-ins had specific conductance from 1000 to 1600 µS/cm with 72 % in 1991 and 63 % in 1992. About 20 % of the samples had specific conductance values greater than 1600 µS/cm during 1991 and 1992. Five samples from 1991 and 1992 had specific conductance values higher than the DWR Criterion of 2200 µS/cm.

Pump-in data presented in Figure 9 shows the mean, maximum, and standard deviation for specific conductance. Data on pump-ins sampled fewer than three times each year are not listed on this figure. Mean values for samples collected in the Aqueduct are shown in the shaded portion of the figure.

Table 15
Frequency of Specific Conductance in San Luis Canal Pump-ins

Interval	1991		1992	
µS/cm	Number	Percent	Number	Percent
< 1000	35	17.4	44	14.9
≥ 1000	166	82.6	251	85.1
≥ 1600	39	19.4	69	23.4
≥ 2200	1	0.4	4	1.4
Total	*201*		*295*	

Figure 9
Specific conductance of pump-ins and the San Luis Canal



Check 21 to Check 29
(mile post 172.26 to 244.54)

Non-project pump-ins located between Check 21 and Check 29 were operated from March to December 1991 and sporadically in 1992 (see Table 1). Samples from the three pump-in sites were analyzed by DWR's Bryte Laboratory.

Arsenic

Concentrations of arsenic at the inflow from the Cross Valley Canal (CVC) ranged from 0.002 mg/l to 0.007 mg/l (mean = 0.004, n = 11) during 1991 and 1992 (Table 16). Levels of arsenic were slightly higher at the West Kern Water District pump-in at mile post 240.20 where values ranged from 0.006 to 0.010 mg/l (mean = 9, n = 11).

Arsenic levels were substantially higher at the outflow from Buena Vista Lake at mile post 242.50. Because of the elevated arsenic levels entering the Aqueduct from April to early July 1991, samples were collected weekly. The maximum concentration observed in the inflow was 0.055 mg/l on April 11, 1991, a value that exceeded the MCL and DWR Policy Criterion of 0.050 mg/l. Following the initial high values in April, arsenic concentrations at that pump-in were reduced to 0.014 mg/l in July. For the period sampled, April 1991 to May 1992, the mean arsenic concentration was 0.021 mg/l.

Selenium

Selenium levels were low at the three pump-ins during 1991 and 1992. Of the 31 samples collected, 30 had selenium values at or below the reporting level of 0.001 mg/l. One sample from the pump-in at mile post 240.20 had a selenium level of 0.002 mg/l.

Nitrate

Concentrations of nitrate in non-project pump-ins were generally in the range found in the Aqueduct. At mile post 238.05, nitrate ranged from 2.2 to 5.8 mg/l (mean = 3.9, n = 12). Nitrate values were lower at the other two pump-in sites in this section of the Aqueduct where the mean levels were 2.4 and 1.1 mg/l at mile posts 240.20 and 242.50, respectively.

Table 16

Water Quality of Pump-ins from Check 21 to Check 29

units = mg/l except specific conductance = µS/cm

	DWR Pump-in Policy Criteria		Cross Valley Canal *MP 238.05*	West Kern Water District *MP 240.20*	Henry Miller Water District *MP 242.50*
Arsenic	0.050	Mean	0.004	0.009	0.021
		Min	0.002	0.006	0.011
		Max	0.007	0.010	0.055
		n	11	11	25
Selenium	0.010	Mean	<0.001	0.001	<0.001
		Min	<0.001	<0.001	<0.001
		Max	<0.001	0.002	<0.001
		n	11	10	10
Nitrate	45	Mean	3.9	2.4	1.1
		Min	2.2	1.6	0.1
		Max	5.8	3.3	2.6
		n	12	14	11
Chloride	600	Mean	40	26	43
		Min	21	16	17
		Max	140	31	88
		n	12	14	11
TDS	1500	Mean	210	212	328
		Min	160	174	173
		Max	417	258	571
		n	11	14	11
Sulfate	600	Mean	36	43	97
		Min	19	27	37
		Max	102	56	192
		n	12	14	11
Specific Conductance	2200	Mean	367	341	526
		Min	263	275	276
		Max	738	403	913
		n	12	14	11

Chloride

Concentrations in the pump-ins were lower than Aqueduct chloride values found at Check 13. At the CVC, chloride ranged from 21 to 140 mg/l (mean = 40, n = 12). Values were in the same range at MP 240.20 (mean = 26, n = 14) and MP 242.50 (mean = 43, n = 11).

Total dissolved solids

TDS ranged from 160 to 417 mg/l in the CVC with 73 % of the samples lower than 200 mg/l. Mean TDS at the CVC and the pump-in at MP 240.20 were similar. TDS at MP 242.50 was higher and ranged from 173 to 571 mg/l (mean = 328, n = 11).

Sulfate

In contrast to sulfate concentrations in the pump-ins located in the San Luis Canal between Check 13 and Check 21, sulfate levels in this section were about equal to or lower than Aqueduct values. At the CVC, sulfate ranged from 19 to 102 mg/l (mean = 36, n = 12). Sulfate concentrations were similar at MP 240.20 where the range in values was narrower (27 to 58 mg/l). At MP 242.50, sulfate was higher than at the two other locations and about 60 % of the samples were less than 100 mg/l.

Specific Conductance

The range in specific conductance at the three pump-ins was 263 to 913 µS/cm. Specific conductance followed the pattern of sulfate where the two stations at MP 238.05 and 240.20 were similar (mean =367 and 341 µS/cm, respectively) and MP 242.50 was higher (mean = 526, n = 11). Mean specific conductance levels at the pump-ins were about equal to or lower than Aqueduct levels.

Check 29 to Check 41
(mile post 244.54 to 303.41)

Non-project pump-ins located from Check 29 to Check 41 of the Aqueduct were sampled from February 1991 to September 1992. Ten pump-ins from the Wheeler Ridge-Maricopa Water Storage District were sampled more than once during this period (Table 17).

Arsenic

Levels of arsenic ranged from the DWR reporting level of less than 0.001 mg/l to 0.010 mg/l (mean = 0.005 mg/l, n = 82). Of the 82 samples examined, 56 % had arsenic concentrations greater than 0.005 mg/l. A similar proportion of samples (21 - 23 %) had concentrations in the intervals of less than or equal to 0.001 mg/l and 0.002 - 0.005 mg/l. Pump-ins with the highest mean values were located at MP 272.53 and 273.75 (Table 17).

Selenium

Concentrations of selenium ranged from less than 0.001 mg/l to 0.014 mg/l for the 95 samples analyzed (mean = 0.002 mg/l). About 58 % of the samples had selenium concentrations less than or equal to 0.001 mg/l and nearly 95 % of the samples had levels of 0.005 mg/l or less. The highest concentration found was 0.014 mg/l in one sample which exceeded the MCL and DWR Policy Criterion of 0.010 mg/l.

Nitrate

Low concentrations of nitrate were present in pump-ins located in this section of the Aqueduct (mean = 0.9 mg/l, n = 85). One sample had a nitrate concentration greater than 3 mg/l which is about the mean annual level found at most Aqueduct locations.

Chloride

Levels of chloride were also lower than those present in the Aqueduct. The mean value of 26 mg/l (n = 85) was considerably lower than the mean 1991 concentration of 117 mg/l found in the Aqueduct at Check 41. Seven samples (8%) had chloride values greater than 50 mg/l (all from MP 269.66).

Table 17
Water Quality of Pump-ins from Check 29 to Check 41
units = mg/l except specific conductance = µS/cm

	DWR Pump-in Policy Criteria	Mile Post	267.46	268.15	269.66	271.21	272.10	272.31	272.53	272.80	273.59	273.75
Arsenic	0.050	Mean	0.001	0.001	0.004	0.007	0.007	0.006	0.008	0.005	0.006	0.008
		Min	<0.001	0.001	0.003	0.006	0.007	0.001	0.007	0.003	0.005	0.006
		Max	0.001	0.002	0.004	0.008	0.008	0.008	0.009	0.006	0.007	0.010
		n	10	9	9	8	5	9	9	7	5	11
Selenium	0.010	Mean	0.002	0.001	0.001	0.002	0.002	0.001	0.001	0.005	0.001	0.002
		Min	0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.001
		Max	0.003	0.002	0.001	0.003	0.003	0.002	0.001	0.012	0.001	0.014
		n	10	9	9	8	5	9	9	8	5	23
Nitrate	45	Mean	1.9	0.9	0.3	0.6	0.7	0.5	0.2	2.3	0.4	1.1
		Min	1.2	0.1	0.1	0.3	0.1	0.3	0.1	0.4	0.1	0.5
		Max	2.6	1.9	0.6	1.4	1.3	1.0	0.5	9.9	0.9	1.6
		n	10	9	11	8	10	4	9	8	5	11
Chloride	600	Mean	27	34	53	12	19	16	18	28	23	21
		Min	25	21	47	8	12	15	13	25	20	19
		Max	29	44	58	18	23	16	23	36	24	23
		n	10	9	11	8	10	4	9	8	5	11
TDS	1500	Mean	1073	1000	711	817	730	692	610	972	878	645
		Min	1020	969	692	767	634	687	549	814	863	606
		Max	1100	1100	724	931	929	695	716	1140	916	679
		n	9	8	11	8	10	4	9	8	5	11
Sulfate	600	Mean	617	541	360	440	383	365	304	536	482	322
		Min	565	489	340	403	317	358	255	425	434	284
		Max	643	622	374	512	506	377	370	662	531	359
		n	10	9	11	8	10	4	9	8	5	11
Specific Conductance	2200	Mean	1431	1371	1090	1153	1033	977	881	1283	1166	925
		Min	1380	1340	1070	1090	921	972	803	1120	1150	886
		Max	1460	1410	1110	1290	1230	986	1000	1460	1200	961
		n	10	9	11	8	10	4	9	8	5	11

Total dissolved solids

TDS values in the non-project pump-ins were about twice as high as levels present in the Aqueduct (mean = 763, n = 83). TDS ranged from 549 to 1140 mg/l (Table 17). Of the 83 samples examined, 52 % had levels less than 750 mg/l while about 18 % had TDS values greater than 1000 mg/l.

Sulfate

As with sulfate levels found in the San Luis Canal (see Check 13 to Check 21), concentration in this section were much higher than Aqueduct values. Sulfate ranged from 255 to 662 mg/l (mean = 433, n = 85). A large proportion (91 %) of samples had sulfate concentrations in the range of 300 to 600 mg/l. Eleven samples (13 %) had sulfate levels that were higher than the DWR Policy Criterion of 600 mg/l.

Specific Conductance

Conductivity ranged from 803 to 1460 µS/cm (mean = 1133, n = 85). These values were higher than levels of specific conductance present in the Aqueduct. Of the 85 samples taken, about 68 % had specific conductance values greater than 1000 µS/cm.

Check 41 to Devil Canyon Afterbay

(mile post 303.41 to 412.88)

Antelope-Valley East Kern Water Agency participated in the pump-in program from May 1991 to January 1992 (Table 5). Water quality samples were collected from June 1991 to January 1992 at six pump-in locations (Table 18).

Arsenic

Concentrations of arsenic in the pump-ins were higher than levels found in the Aqueduct. Pump-in arsenic values ranged from 0.006 to 0.021 mg/l (mean = 0.012 mg/l, n = 40). The highest arsenic concentration reported in the Aqueduct at Check 41 from 1989 to 1992 was 0.006 mg/l which is the minimum found in the pump-ins. Of the 40 samples examined, 60 % had arsenic concentrations greater than 0.010 mg/l and about 13 % were higher than 0.015 mg/l.

Selenium

Low selenium levels were found in all the pump-in samples. All samples had selenium levels less than or equal to the range found in the Aqueduct, 0.001 mg/l.

Nitrate

Substantially higher levels of nitrate were found in the pump-ins than in the Aqueduct at Check 41. Pump-in concentrations of nitrate ranged from 11 to 23 mg/l (mean = 15.0, n= 43) compared to a range of about 2 to 5 mg/l at Check 41. Of the 43 samples examined, about 44 % had nitrate levels greater than 15 mg/l and 4 samples (9 %) had concentrations greater than 20 mg/l (Table 18).

Chloride

Aqueduct levels of chloride at Check 41 were about 10 times higher than concentrations present in the pump-in samples. Chloride concentrations in the pump-ins ranged from 10 to 18 mg/l (mean = 13.8, n = 43).

Table 18

Water Quality of Pump-ins between Check 41 to Devil Canyon Afterbay

units = mg/l except specific conductance = µS/cm

	DWR Pump-In Policy Criteria	Mile post	306.50	307.24	308.08	310.30	311.60	311.65
Arsenic	0.050	Mean	0.010	0.012	0.012	0.011	0.017	0.007
		Min	0.008	0.011	0.010	0.010	0.007	0.006
		Max	0.013	0.013	0.015	0.013	0.021	0.008
		n	7	7	7	7	7	5
Selenium	0.010	Mean	0.001	<0.001	0.001	0.001	<0.001	<0.001
		Min	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		Max	0.001	<0.001	0.001	0.001	<0.001	<0.001
		n	7	7	7	7	7	5
Nitrate	45	Mean	17.0	19.4	11.9	13.1	15.5	13.3
		Min	15.0	16.0	11.0	12.0	13.0	12.0
		Max	20.0	23.0	14.0	15.0	18.0	16.0
		n	7	7	7	8	8	6
Chloride	600	Mean	17	13	13	17	12	10
		Min	15	12	13	16	11	10
		Max	18	14	14	18	15	11
		n	7	7	7	8	8	6
TDS	1500	Mean	315	283	315	344	291	297
		Min	311	279	308	332	285	293
		Max	320	292	319	359	316	302
		n	7	7	7	8	8	6
Sulfate	600	Mean	49	45	47	60	37	46
		Min	47	43	45	58	34	45
		Max	50	47	48	60	47	46
		n	7	7	7	8	8	6
Specific Conductance	2200	Mean	491	415	504	523	418	459
		Min	487	408	500	512	406	457
		Max	496	426	509	529	469	460
		n	7	7	7	8	8	6

Total dissolved solids

TDS values of the pump-ins were similar to levels present in the Aqueduct at Check 41. Samples from the pump-ins had TDS levels in a narrow range from 279 to 359 mg/l (mean = 308, n = 43). In comparison, the 1991 mean TDS value at Check 41 in the Aqueduct was 419 mg/l.

Sulfate

Levels of sulfate in the pump-ins were about 50 % lower than those found in the Aqueduct at Check 41. Pump-in concentrations of sulfate ranged from 34 to 60 mg/l (mean = 47.1, n = 43) compared to the 1991 mean sulfate level of 87 mg/l at Check 41. (Table 18).

Specific Conductance

Conductivity levels were lower in the pump-ins than in the Aqueduct at Check 41 and ranged from 406 to 529 µS/cm (mean = 468, n = 43). Mean specific conductance at Check 41 was 732 µS/cm in 1991 which was 264 µS/cm higher than found in pump-in samples.

Part 4
Effects on Aqueduct Water Quality

The effects of ground water pump-ins on water quality in the Aqueduct are discussed in this section. A number of Aqueduct stations were monitored on a monthly basis to evaluate the influence of the non-project inflows. Constituent levels at stations below pump-ins were compared to above station values to determine the effects of pump-in on Aqueduct water quality.

Banks Pumping Plant to Check 13

Non-project pump-in from the Oak Flat Water District had minimal effect on Aqueduct water quality. Although levels of selenium and nitrate were high and exceeded the DWR Policy Criteria, the total amount of water pumped into the Aqueduct was only 128 acre-feet over a two month period (Table 5).

With the exception of arsenic, pump-in constituent levels (Table 8) were higher than those in the Aqueduct at Banks Pumping Plant (A-1 to A-9). Arsenic values at the single pump-in were about equal to or lower than Aqueduct concentrations. Aqueduct concentrations did not appear to be affected by the Oak Flat Water District pump-in.

Check 13 to Check 21 (San Luis Canal)

Arsenic

Monthly arsenic concentrations from 1989 to 1992 as determined by DWR sampling and analysis are presented in Table A-1. From January 1989 to March 1991 monthly arsenic concentrations at Check 13 and Check 21 ranged from less than 0.001 mg/l to 0.003 mg/l (Table A–1). Although the pump-in program began in June 1990, the volume of water conveyed monthly into the Aqueduct via ground water pump-ins did not exceed 2000 acre -feet until April 1991 (Table 5).

It appears that arsenic levels in the Aqueduct below Check 13 increased as a result of non-project pump-ins. Prior to the start of the pump-in program, there were no instances when monthly arsenic concentrations at Check 21 were higher than Check 13 (Table A-1). During months when monthly pump-in to the San Luis Canal exceeded 2000 acre-feet (April 1991 to December 1992), arsenic at Check 21 was 0.001 mg/l higher than concentrations at Check 13 in 33 % of the months (7 out of 21). For that same period, non-project pump-ins made up from about 3 % to 46 % of the monthly outflow at Check 21 (Table 7). Pump-in data during most of 1992 was not reported to less than 0.004 mg/l and was not included in this analysis.

A comparison between an upstream station (downstream of Check 13 at mile post 104.19) and downstream site (near Check 21 at mile post 172.58) is presented in Table 19 (USBR supplied data). An upstream to downstream comparison of the arsenic concentrations was difficult using the USBR data because of limited data in 1991 (four samples) and the analytical method used in 1992. In 1992, the reporting level of 0.005 mg/l was *higher* than arsenic concentrations in the Aqueduct.

In summary, non-project pump-ins appear to have increased arsenic concentrations at Check 21 based on the following data : (a) non-project pump-ins made up a considerable proportion of the Check 21 outflow during some months; (b) during the pump-in program, monthly arsenic concentrations at Check 21 were 0.001 mg/l higher than at Check 13 in one third of the samples while there were no cases of elevated levels at Check 21 in the prior 25 months; and (c) about 50% of the pump-ins sampled in 1991 had arsenic concentrations higher than those in the Aqueduct at Check 13 which is above the influence of the pump-ins.

Selenium

There was no detectable increase in selenium levels at Check 21 from non-project pump-ins to the San Luis Canal. Monthly Aqueduct data is presented from 1989 to 1992 in Table A-2. Monthly selenium levels at Check 13 and Check 21 were at or less than 0.001 mg/l in all but one sample. One sample collected in May 1991 from Check 21 had a selenium value of 0.002 mg/l.

A number of the pump-ins with elevated selenium levels were either shut down, blended with water from another well, or blended with Westlands Water District water. Selenium concentrations in the Aqueduct reported by USBR are shown in Figure 4 (shaded area). The apparent higher selenium levels in the Aqueduct in 1992 (Figure 4, bottom panel) resulted from a higher reporting level used in the analysis from April to December 1992 (see Methods).

Table 19
San Luis Canal Water Quality Above and Below Pump-ins

Constituent	Year	Upstream (MP 104.19) Mean	SD	Number	Downstream (MP 172.58) Mean	SD	Number	Downstream Change
Arsenic (mg/l)	1991[1]	0.0027	0.001	4	0.0033	0.001	4	0.0006
	1992[2]	<0.005	0	12	< 0.005	0	12	0
Selenium (mg/l)	1991[1]	< 0.002	0	4	< 0.002	0	4	0
	1992[2]	< 0.005	0	12	< 0.005	0	12	0
Chloride (mg/l)	1991	110.8	20.5	4	103.5	15.4	4	-7.3
	1992	123.0	25.8	12	120.9	18.1	12	-2.1
Sulfate (mg/l)	1991	36.8	9.7	4	89.5	14.7	4	52.7
	1992	59.4	10.5	12	105.1	37.1	12	45.7
Specific conductance (µS/cm)	1991	580.0	87.6	4	680.0	63.8	12	100.0
	1992	672.3	85.6	12	767.5	126.6	12	95.2
TDS (mg/l)	1991	322.5	49.9	4	405.0	34.2	4	82.5
	1992	384.5	54.6	12	445.8	83.3	12	61.3
Nitrate (mg/l)	1991	2.3	1.3	4	3.0	0.8	4	0.7
	1992	3.7	1.7	12	4.2	2.1	12	0.5

1 Reporting level = 0.002 mg/l
2 Reporting level of 0.005 mg/l was higher than in 1991
SD = Standard deviation

Nitrate

Pump-ins to the San Luis Canal did not appear to affect nitrate concentrations in the Aqueduct at Check 21. The greatest influence on nitrate levels in this section of the Aqueduct appears to be the Delta Mendota Canal (Table A-3).

Data on nitrate concentrations were limited during the two years prior to pump-ins (1989 and 1990). In the two years of pump-in, 1991 and 1992, mean nitrate concentrations were not significantly (Student's *t*-test, $P>0.05$) different at Check 21 (3.64 ± 0.24 mg/l, n=23)[1] than Check 13 (3.68 ± 0.33 mg/l, n=23). In 1992, mean nitrate levels at Check 13 were 3.9 mg/l compared to 3.4 mg/l in 1991.

Flows entering the Aqueduct from the Delta Mendota Canal had higher levels of nitrate than concentrations at Banks Pumping Plant. Nitrate concentrations in the Delta Mendota Canal ranged from 2.0 to 12.0 mg/l in 1991 and 1992. Mean nitrate was significantly (Student's *t*-test, $P<0.05$) higher at the DMC (4.37 ± 0.49 mg/l, n=23) than Banks Pumping Plant (2.89 ± 0.45 mg/l, n=23). The influence of the DMC appears to increase nitrate at Check 13 to higher concentrations than those at Banks Pumping Plant. In fact, mean nitrate concentrations were significantly higher ($P<0.05$) at Check 13 (3.67 ± 0.33 mg/l, n=23) than Banks Pumping Plant (2.89 ± 0.45 mg/l, n=23) in 1991 and 1992.

[1] Convention used throughout this section is (mean ± standard error, n = number of samples used in the calculations)

Chloride

Concentrations of chloride in the pump-ins to the San Luis Canal were mostly equal to or lower than levels in the Aqueduct at Check 13 (Table A-4). Aqueduct chloride levels were lowest in 1989 at Banks Pumping Plant and mean annual concentrations have fluctuated from 105 to 121 mg/l during 1990 to 1992.

Chloride values at Check 13 were similar to those at Banks Pumping Plant from 1989 to 1992. In contrast to nitrate levels, chloride did not increase at Check 13 as a result of the influence of the DMC. Mean chloride concentrations were not significantly different in the DMC than Banks Pumping Plant.

At Check 21, a comparison was done between chloride levels for the two years before pump-in (1989 and 1990) with two years of pump-in activity (1991 and 1992). Mean chloride values were not significantly (Student's *t*-test, $P>0.05$) higher in 1991 and 1992 (120.4 ± 4.9 mg/l, n=24) than 1989 and 1990 (107.9 ± 5.5 mg/l, n=24). Non-project pump-ins appear to have little or no effect on chloride concentrations in the San Luis Canal.

Total Dissolved Solids

Most of the pump-ins had higher levels of TDS than values in the San Luis Canal. At Check 13, mean annual TDS ranged from 320 to 369 mg/l during 1989 to 1992 (Table A-8).

At Check 21 there was a noticeable increase in mean TDS in 1991 while values at Check 13 did not increase during the same period. Prior to pump-in (1989 and 1990), monthly TDS in the Aqueduct at Check 21 was greater than 400 mg/l for two months. In 1991 and 1992, 17 of 24 (70 %) of the monthly samples had TDS values greater than 400 mg/l.

Mean TDS values were compared for 1989 and 1990 with 1991 and 1992. Mean TDS was significantly higher in 1991 and 1992 (436.4 ± 14.2 mg/l, n = 24) than in the years before pump-in began (336.8 ± 14.0 mg/l, n=24). These results show that non-project pump-ins contributed to higher TDS levels in the San Luis Canal.

Sulfate

Concentrations of sulfate increased substantially in the San Luis Canal as a result of non-project pump-ins while upstream values did not change significantly (Table A-7). At Banks Pumping Plant, mean annual sulfate levels increased by about 10 mg/l from 1989 (34 mg/l) to 1992 (44 mg/l), however, the values were not significantly different over the four year period of 1989 to 1992 (Student's *t*-test, $P>0.05$).

At Check 13, a similar trend is evident with higher mean annual sulfate levels in 1992 (54 mg/l) than 1989 (43 mg/l). In addition, mean sulfate concentrations at Check 13 average about 9 to 13 mg/l higher than those at Banks Pumping Plant from 1989 to 1992 (Table A-7). The main cause of higher sulfate at Check 13 appears to be from the influence of the Delta Mendota Canal (DMC) where mean annual sulfate levels were from about 10 to 28 mg/l higher than at Banks Pumping Plant in 1990 to 1992.

Prior to large scale pump-ins during 1989 and 1990, mean annual sulfate concentrations were not significantly (Student's *t*-test, $P>0.05$) different at Check 21 (42.9 ± 2.2 mg/l, n=24) than Check 13 (45.1 ± 2.6 mg/l, n=24). In 1991, the volume of water conveyed into the San Luis Canal from pump-ins increased and resulted in significantly ($P<0.05$) higher sulfate concentrations at Check 21 (86 ± 7.3 mg/l, n=12) than Check 13 (49.6 ± 3.7 mg/l, n=12).

The effects of pump-in on Aqueduct water quality was even greater in 1992 when the total volume of water increased to about 130,000 acre-feet. In 1992, mean sulfate concentrations were again significantly ($P<0.05$) higher at Check 21 (103 ± 11.7 mg/l, n=12) than Check 13 (54 ± 2.7 mg/l, n=12). These concentrations were considerably below the DWR Pump-in Policy criterion of 600 mg/l.

Table 20
Sulfate Concentrations (mg/l) in the San Luis Canal
(SD = standard deviation, n = number of samples taken)

Milepost	Location	1991 Mean	1991 SD	1991 n	1992 Mean	1992 SD	1992 n
104.19	Upstream	36.8	9.8	4	59.4	10.5	12
108.46	Check 15	45.0	5.7	2	62.8	12.5	12
122.05	Check 16	66.0	1.4	2	80.2	20.3	12
132.94	Check 17	62.5	7.8	2	81.0	22.1	12
143.21	Check 18	96.5	33.2	2	140.7	109.4	11
155.63	Check 19	73.0	5.7	2	92.9	28.0	12
164.68	Check 20	112.5	38.9	2	109.4	32.0	11
172.58	Check 21	89.5	14.7	4	105.1	37.1	12

Data collected by Westlands Water District at 8 stations between Check 13 and Check 21 in 1991 and 1992 are shown in Table 20. Mean annual sulfate concentrations were similar to DWR data (Table A-7). In 1991, data was too limited for comparisons with only two samples collected at 6 of 8 stations. In 1992, 11 or 12 samples were taken at each of the 8 stations. Mean sulfate concentrations increased by 45.7 mg/l from mile post 104.19 (59.4 mg/l) to mile post 172.58 (105.1 mg/l). Sulfate levels increased by more than 0.5 mg/l per Aqueduct mile during 1992. Sulfate values from Check 18 were highly variable with a standard deviation about equal to the sample mean.

In summary, sulfate concentrations were significantly higher in the San Luis Canal as a result of non-project pump-ins. Mean 1992 sulfate values at Check 21 (103 mg/l) were nearly twice as high as those upstream of the pump-ins at Check 13.

Specific Conductance

Mean specific conductance at Banks Pumping Plant has increased since 1989 when the annual mean was 478 µS/cm (Table A-9). A similar pattern of increasing specific conductance was apparent at Check 13 over the four year period. Although Check 13 specific conductance appeared higher in 1990 (625 ± 26.1 µS/cm, n=12) than 1989 (557 ± 41.5 µS/cm, n=12), the values were not significantly different (Student's *t* - test, $P>0.05$).

Mean specific conductance at Check 21 greatly increased in 1991 with the start of non-project pump-ins. Mean conductivity at Check 21 was significantly higher in 1991 and 1992 (759 ± 23.4 µS/cm, n=24) than in 1989 and 1990 (604 ± 24.2 µS/cm, n=24). The levels of specific conductance in the pump-ins were considerably higher than those in the Aqueduct (Table 15). More than 80 % of the pump-ins had specific conductance values greater than 1000 µS/cm which is higher than the maximum Aqueduct values (Table A-9).

Check 21 to Devil Canyon Afterbay

Arsenic

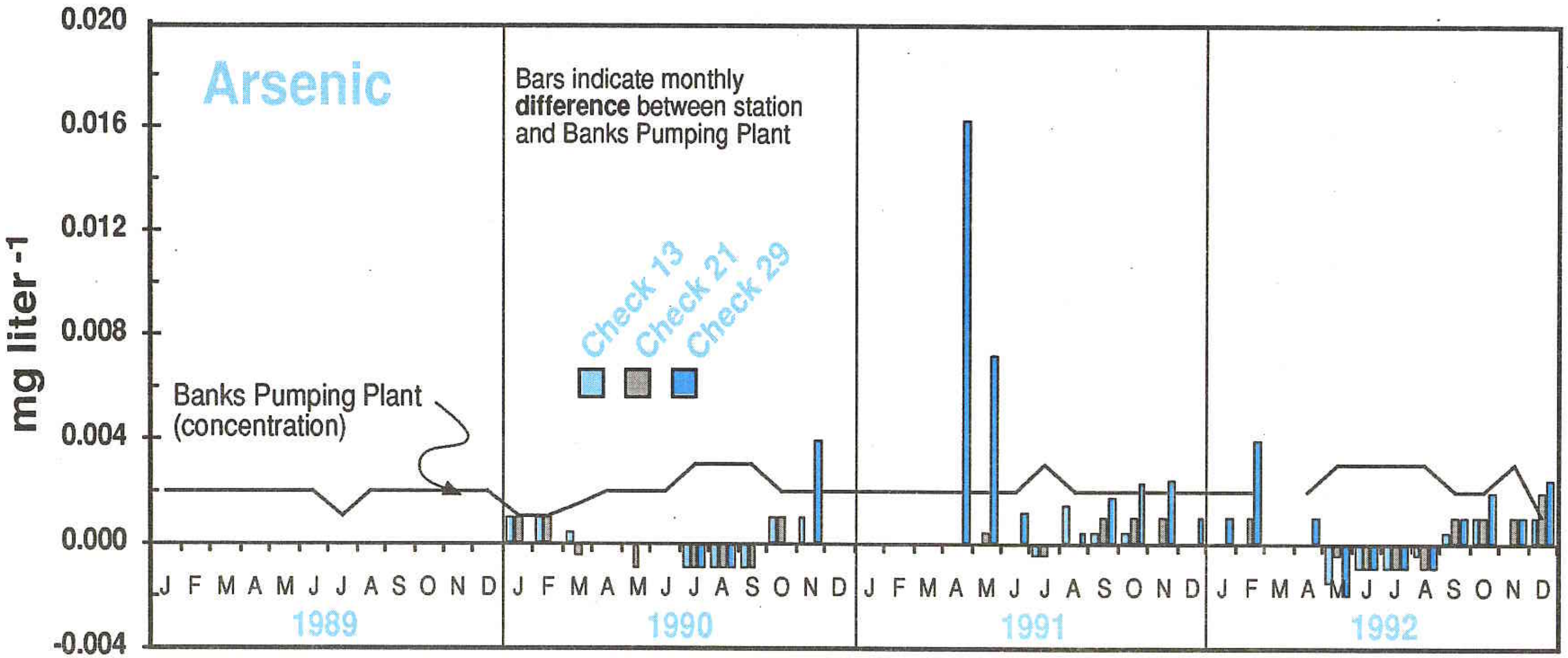
Arsenic concentrations in the Aqueduct below Check 21 appeared to increase because of non-project pump-ins. The greatest influence on Aqueduct arsenic levels was from pump-ins located between Check 21 and Check 29 during early 1991. At stations located farther down Aqueduct, there were no significant changes in Aqueduct arsenic concentrations.

Mean arsenic concentrations in the Aqueduct during 1989 to 1992 are presented for Banks Plant, Check 13, Check 21, and Check 29 (Figure 10). Actual concentrations are shown for Banks Pumping Plant, values shown for the other stations are presented as the difference between Banks and that station. Positive numbers indicate that concentrations at a station were higher than at Banks, while negative values indicate concentrations lower than at Banks.

Arsenic concentrations increased to 0.018 mg/l during April 1991 at Check 29 from Buena Vista Lake inflows. Mean arsenic concentrations, however, were not significantly different in 1991 at Check 29 (0.0048 $\pm$ 0.001 mg/l, n=12) than Check 21 (0.0024 $\pm$ 0.0001 mg/l, n=12). Arsenic concentrations were elevated at Check 29 during April and May 1991 (0.009 mg/l) and thereafter were within 0.001 to 0.002 mg/l of those at Check 21.

Figure 10

Monthly arsenic concentrations in the aqueduct, 1989 — 1992

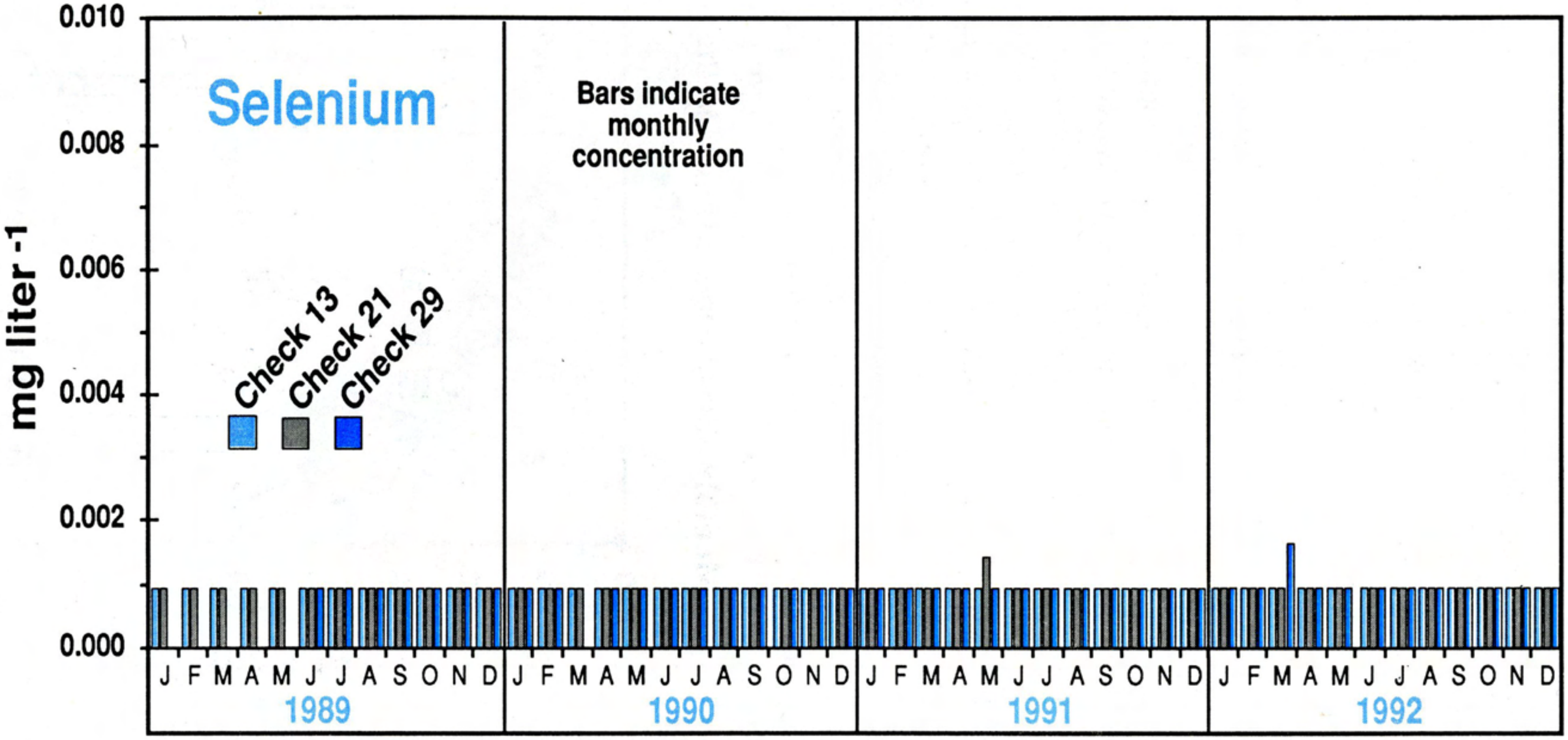


Selenium

Pump-ins located below Check 21 did not appear to affect Aqueduct concentrations of selenium (Figure 11, Table A-2). Mean annual concentrations were equal to or less than 0.001 mg/l from 1989 to 1992 at Banks Pumping Plant. DMC, Check 13, Check 21, Check 29, Check 41, and Devil Canyon. Nearly all monthly samples had selenium concentrations equal to or less than 0.001 mg/l.

Selenium concentrations were highest in pump-ins operated by Wheeler Ridge-Maricopa Water Storage District and located between Check 29 and Check 41. Although a number of samples had concentrations higher than the reporting level of 0.001 mg/l (Table 17), selenium values at Check 41 were not significantly different than Check 29.

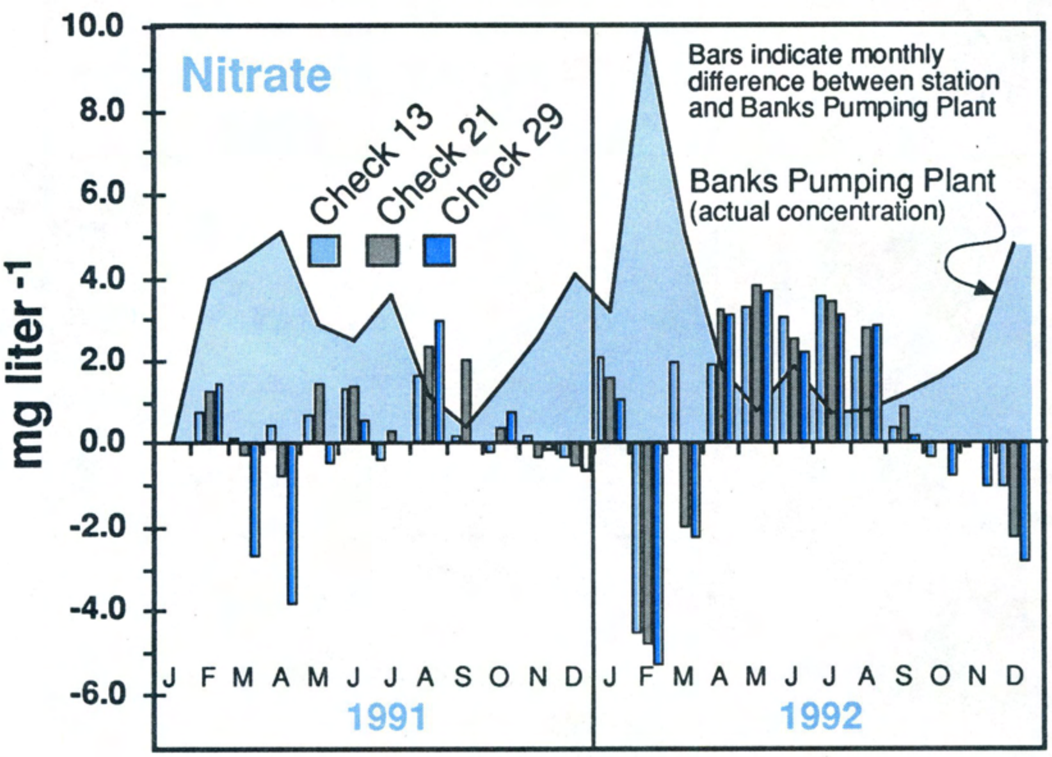
Figure 11
Monthly selenium concentrations in the aqueduct, 1989 — 1992



Nitrate Nitrate concentrations of pump-ins located from Check 21 to Check 29 and Check 29 to Check 41 were about equal to or lower than Aqueduct levels (Figure 12). Mean Aqueduct concentrations of nitrate ranged from about 2.5 to 3.6 mg/l between Check 21 and Devil Canyon Afterbay (Table A-3).

In contrast to the upper sections of the Aqueduct, nitrate concentrations at pump-ins located below Check 41 (AVEK) were substantially higher than Aqueduct levels. During the eight months of active pump-in (May to December 1991), the mean Aqueduct concentration of nitrate was 15.0 mg/l (Table 18). Mean nitrate concentrations at Devil Canyon Afterbay (mean=2.8 ± 0.27, n=8) were similar to Check 41 (mean=3.1 ± 0.28, n=7) during that eight month period. The volume of water pumped into the Aqueduct below Check 41 was low, with a monthly average of about 1400 acre-feet. Total nitrate loading from pump-ins was low and did not result in any detectable effect on Aqueduct nitrate concentrations.

Figure 12
Monthly nitrate concentrations in the aqueduct, 1991 — 1992

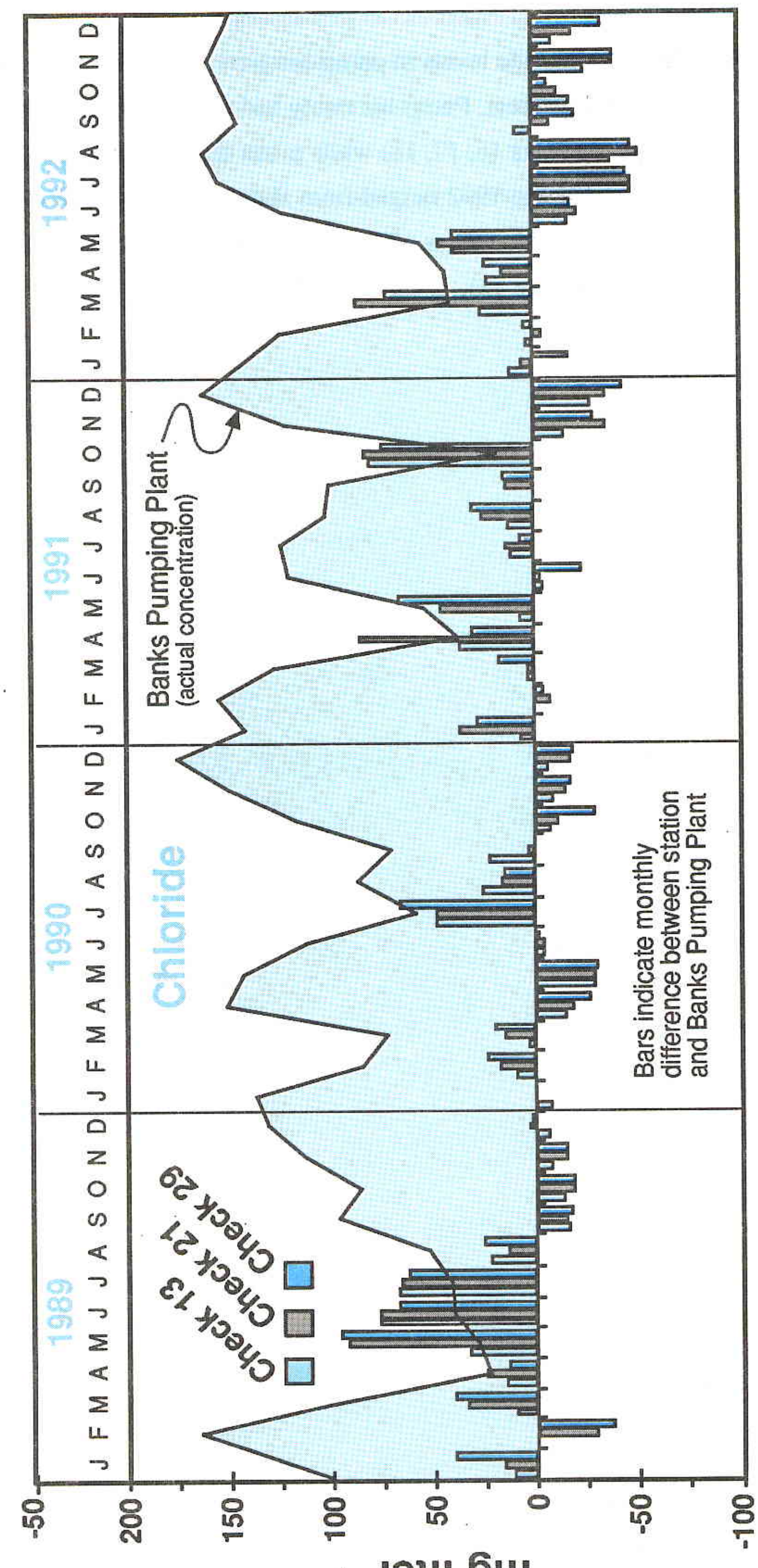


Chloride

Chloride levels in pump-ins were generally lower than values in the Aqueduct. Pump-ins rarely had chloride values greater than 40 mg/l (Tables 16, 17, 18) while mean chloride values in the Aqueduct during 1989 to 1992 ranged from about 95 to 124 mg/l (Table A-4). The low chloride values of pump-ins did not affect Aqueduct concentrations (Figure 13).

Figure 13

Monthly chloride concentrations in the aqueduct, 1989 — 1992



Hardness

Pump-in samples were not analyzed for hardness but hardness was routinely monitored in the Aqueduct. Hardness levels in the Aqueduct have increased since 1989 because of higher concentrations entering the SWP at Banks and from pump-in activities (Table A-5).

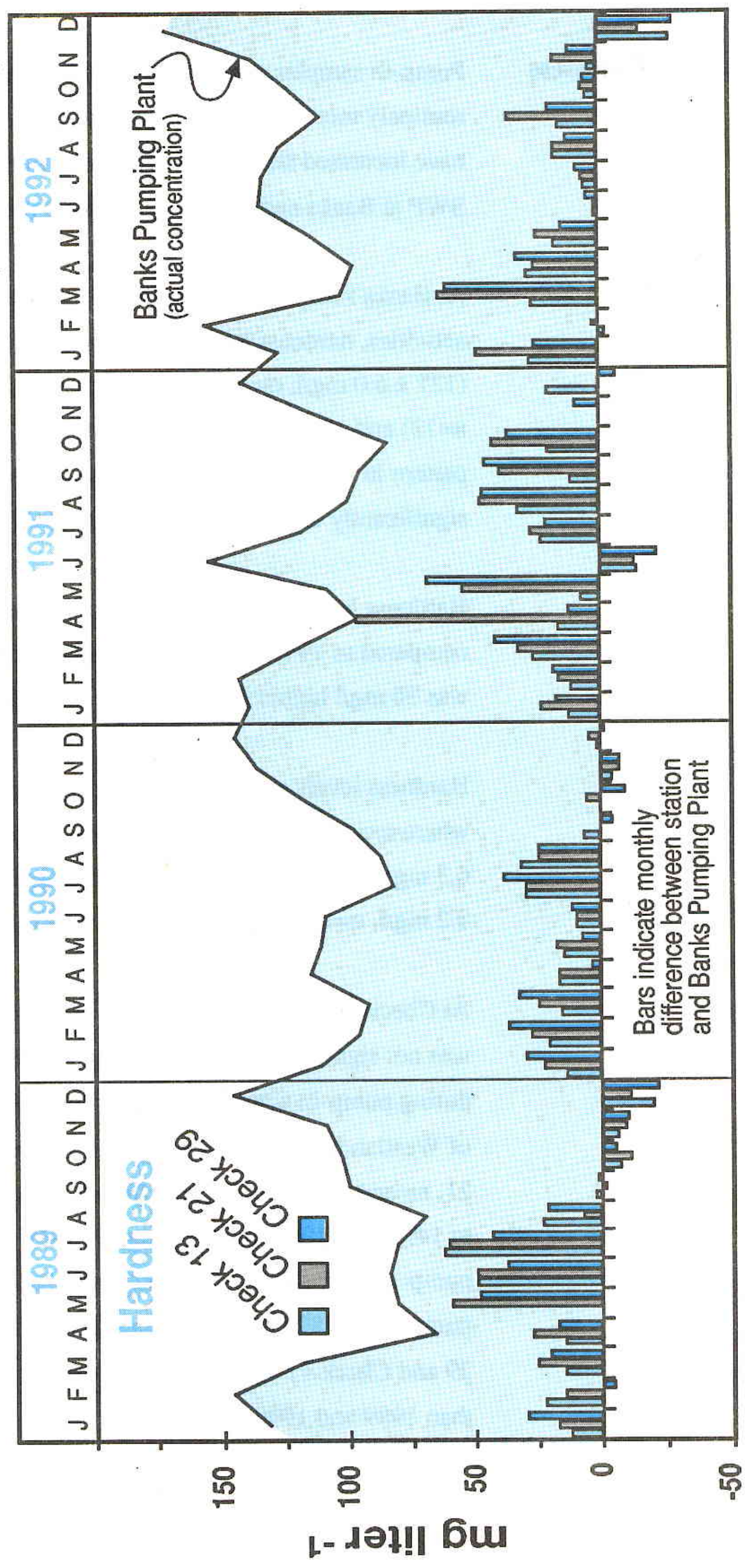
At Banks Pumping Plant which is upstream of the influence of pump-in activities, hardness has increased since 1991. Mean hardness in 1992 (127 ± 6.0 mg/l, n=12) was significantly higher than in 1989 (103 ± 8.1, n=12) and 1990 (108 ± 5.5 mg/l, n=12) . The data follows the same pattern in 1991 where mean hardness (118 ± 6.5 mg/l, n=12) was significantly higher than 1989 and 1990 (108 ± 5.5 mg/l, n=12).

Hardness levels at the DMC also increased substantially in 1992 compared to 1990 and 1991 values. Mean hardness in 1992 of 161 mg/l was 36 mg/l higher than the 1990 and 1989 values of 125 mg/l.

Hardness levels at Check 13 were similar to Banks Pumping Plant where mean levels at Check 13 were significantly higher in 1991 (132 ± 6.3 mg/l, n=12) and 1992 (138 ± 3.0 mg/l, n=12) than 1989 (121 ± 8.2 mg/l, n=12). Mean hardness was also higher in 1992 than 1990.

At Check 21, Check 29, and Check 41 mean hardness in 1989 and 1990 was not significantly different than values at Check 13. However, during pump-in activities in 1991 and 1992, mean hardness downstream of Westlands Water District pump-ins increased significantly. At Check 21, mean hardness increased from 122 mg/l (1989) and 123 mg/l (1990) to 149 mg/l (1991) and 147 mg/l (1992). Mean hardness during the pump-in years (1991 and 1992) was significantly higher than before pump-ins (1989 and 1990). Hardness followed the same trend at Check 29 and Check 41 where 1991 and 1992 values were significantly higher than 1989 and 1990 (Figure 14).

Figure 14
Monthly hardness concentrations in the aqueduct, 1989 — 1992



Sodium

Pump-in samples were not analyzed for sodium concentrations but analysis was routinely conducted on Aqueduct samples. In the Aqueduct, sodium levels increased between Check 13 and Check 21 during pump-ins (Table A-6).

At Banks Pumping Plant sodium levels have increased since 1989. Mean sodium in 1989 was significantly lower (55 ± 7.4 mg/l, n=12) than 1990 (71 ± 6.3 mg/l, n=12); 1991 (66 ± 7.4 mg/l, n=12); and 1992 (76.1 ± 7.2 mg/l, n=12).

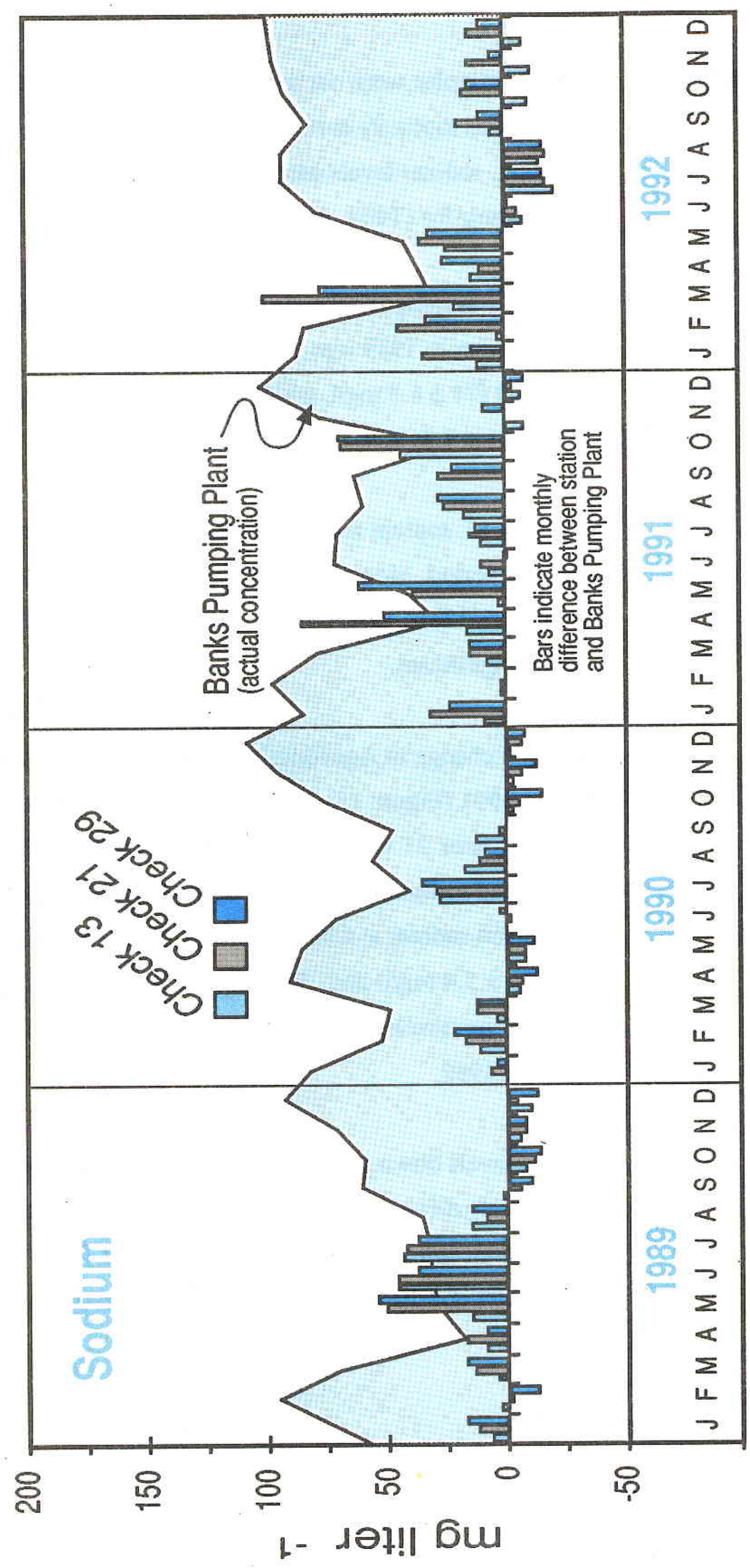
At Check 13, sodium levels have not changed appreciably over the past four year period. Mean sodium increased somewhat from 1989 (66 ± 5.5 mg/l, n=12) to 1992 (76 ± 4.3 mg/l, n=12), however, the difference was not significant.

The main change in Aqueduct sodium levels occurred at Check 21 from 1990 to 1991 (Figure 15). Prior to pump-in (1989 and 1990), sodium levels at Check 21 were not significantly different than Check 13. In 1991, mean sodium at Check 21 increased by 18 mg/l over 1990 values while mean sodium at Check 13 was similar in 1990 (75 ± 4.0 mg/l), 1991 (75 ± 5.4 mg/l) and 1992 (76 ± 4.3 mg/l). In addition, Check 21 mean sodium levels were significantly higher than Check 13 values in 1991 and 1992.

Sodium levels down aqueduct at Check 29 and Check 41 were not significantly different than Check 21 levels during the same year. Sodium concentrations at those two locations followed the same pattern where 1991 and 1992 levels were higher than those in 1989 and 1990.

Figure 15

Monthly sodium concentrations in the aqueduct, 1989 — 1992



Sulfate Pump-ins located from Checks 21 to 29 and Check 41 to Devil Canyon Afterbay had lower sulfate concentrations than the Aqueduct. In contrast, pump-ins located from Check 29 to 41 (Wheeler Ridge-Maricopa Water Storage District) had sulfate levels substantially higher than the Aqueduct. In fact, mean sulfate concentrations (433 mg/l, n=85) of WRM pump-ins were similar to sulfate levels of pump-ins to the San Luis Canal in 1991 (mean=450 mg/l, n=214) and 1992 (mean=478, n=321).

Pump-ins had no detectable effect on Aqueduct sulfate concentrations at Check 29 (Table A-7). While overall sulfate concentrations increased at Check 29 in 1991 and 1992 (Figure 16), sulfate concentrations at Check 29 were not different than Check 21 for the same two years.

Although pump-in sulfate concentrations in the Wheeler Ridge-Maricopa Water Storage District were high, those pump-ins did not appear to have detectable effects on Aqueduct sulfate levels at Check 41. The pump-in volumes of 9,125 acre-feet in 1991 and 7,131 acre-feet in 1992 made up a small proportion of the total Aqueduct flow.

When sulfate values during the two years preceding pump-in (1989 and 1990) were compared, Check 41 (mean=45.5 ± 2.5 mg/l, n=23) was not significantly different than Check 29 (44.1 ± 2.7 mg/l, n=23). When the two years of pump-in (1991 and 1992) were compared, mean sulfate values at Check 41 (90.7 ± 3.9 mg/l, n=22) were again not significantly (Student's *t*-test, $P>0.05$) different than Check 29 (90.7 ± 5.5 mg/l, n=22).

In the Aqueduct, mean sulfate concentrations in 1991 and 1992 at Devil Canyon (63 and 75 mg/l) were lower than values at Check 41 (87 and 94 mg/l). Pump-ins operated by AVEK had sulfate concentrations lower than Aqueduct levels, however, it appears that these pump-ins have no effect on Aqueduct sulfate levels in 1991.

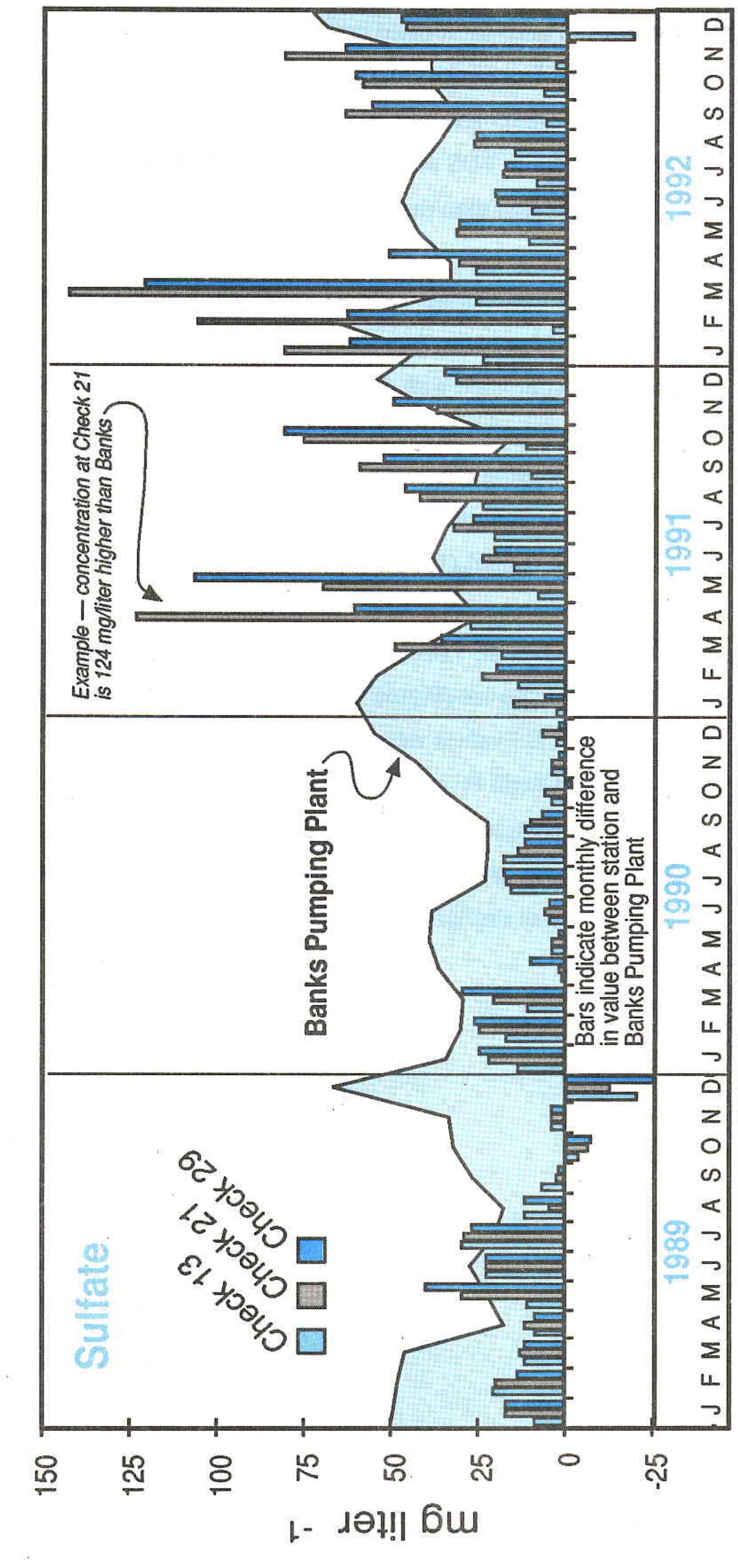
AVEK pump-in were active from May to December 1991. In the two years prior to any Aqueduct pump-ins there was no detectable differences in May to December mean sulfate concentrations at Devil Canyon Afterbay (1989: 38 ± 2.9 mg/l, n=7) or (1990: 48 ± 2.8 mg/l, n=6) and Check 41 (1989: 40 ± 2.9 mg/l, n=7) or (1990: 44 ± 2.6, n=7).

During 1991 and 1992, mean sulfate concentrations increased both at Devil Canyon Afterbay and Check 41 compared to 1989 and 1990 due to up Aqueduct pump-ins. While sulfate concentrations were lower at Devil Canyon than Check 41 in 1991 and 1992, there was no difference in sulfate values *at* Devil Canyon during those two years (1991: 68 ± 6.2, n=8; 1992: 75 ± 5.2, n=9). In addition the change in sulfate from Check 41 to Devil Canyon was similar during 1991 (15 mg/l) and 1992 (16 mg/l) although AVEK pump-ins were active only in 1991. Based on this data, AVEK pump-ins did not have any detectable effect on Aqueduct sulfate values.

In summary, sulfate concentrations at Checks 21, 29, 41 and Devil Canyon Afterbay increased in 1991 and 1992 compared to the period before pump-in (1989 and 1990). However, pump-ins located below Check 21 had no detectable effect on Aqueduct sulfate concentrations.

Figure 16

Monthly sulfate concentrations in the aqueduct, 1989 — 1992



Total Dissolved Solids

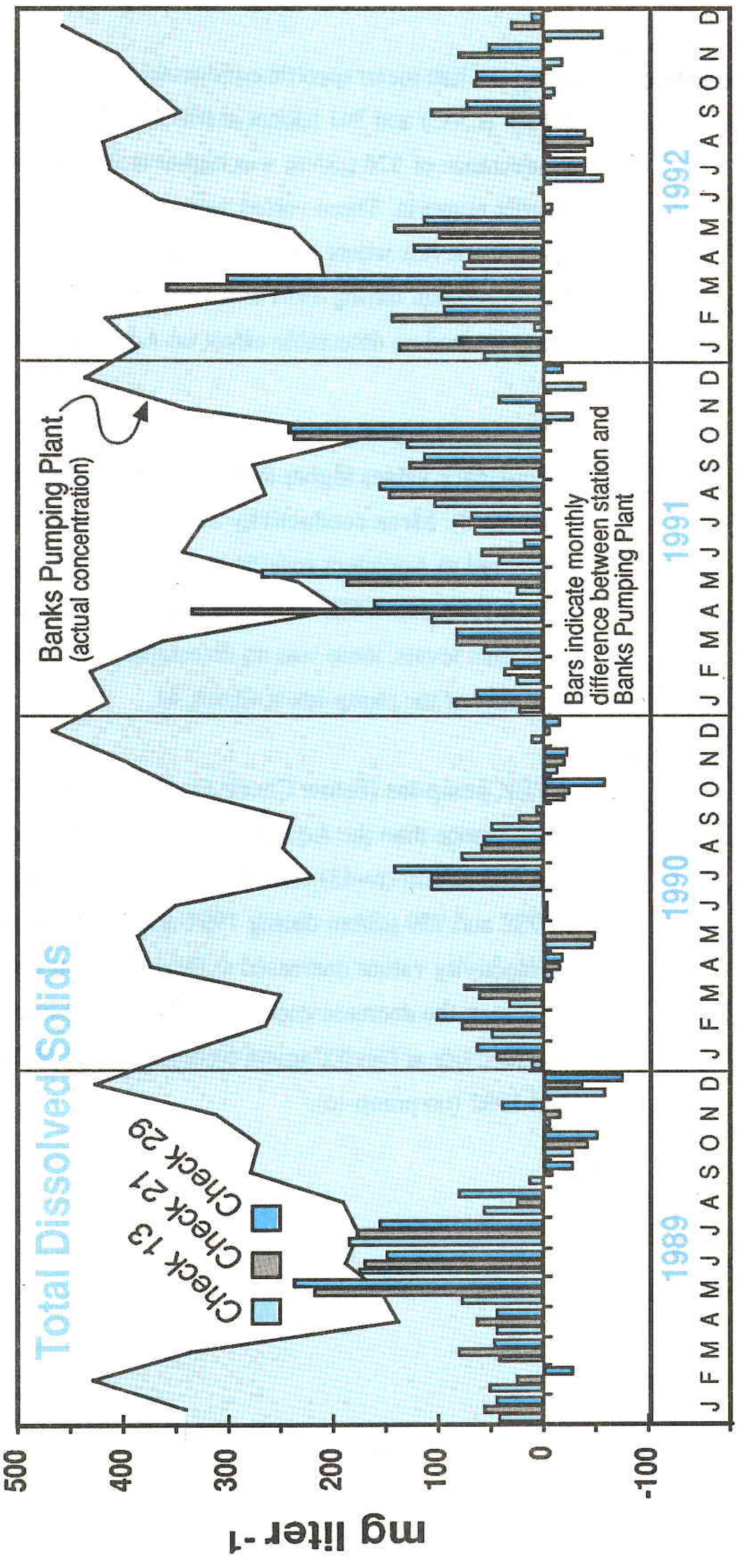
Pump-ins located between Check 21 and Check 29 had no detectable effect on Aqueduct TDS levels (Table A-8). Pump-ins located at MP 238.05 and 240.20 had TDS levels in the range of those in the Aqueduct while TDS at MP 242.50 (Henry Miller Water District) had TDS values higher than the Aqueduct (Table 16).

From Checks 29 to 41, pump-ins had TDS values about twice as high as those in the Aqueduct. Mean TDS for pump-ins was 763 mg/l (n=83) compared with Check 29 Aqueduct values of 417 mg/l in 1991 and 424 mg/l in 1992. The high pump-in TDS values had a low total loading due to low pump-in volumes and had no detectable effect on Aqueduct TDS at Check 41 where the mean was 419 mg/l (1991) and 433 mg/l (1992).

Overall, TDS values increased down Aqueduct of Check 13 during pump-ins (Figure 17). At pump-ins located below Check 41 (AVEK), TDS values were slightly lower than Check 41 Aqueduct values. At Check 41, mean TDS was 419 mg/l (1991) and 433 mg/l (1992) compared to pump-in TDS of 308 mg/l (n=43). As with sulfate, TDS was lower at Devil Canyon than Check 41 in 1991 and 1992 while TDS was similar at those two stations in 1989 and 1990.

Figure 17

Monthly total dissolved solids in the aqueduct, 1989 — 1992



Specific Conductance

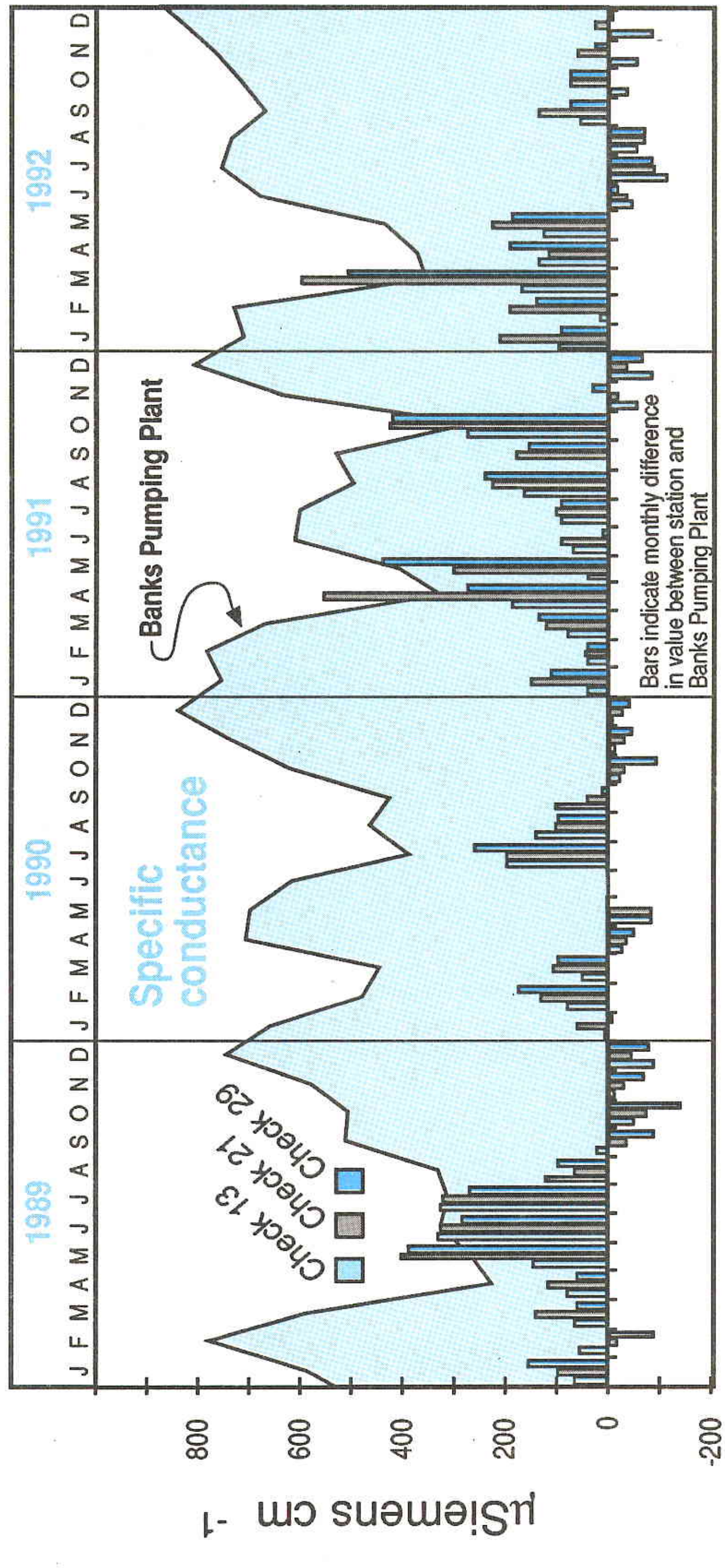
Pump-ins had mean specific conductance values of 367 µS/cm at MP 238.05 (CVC) and 341 µS/cm at MP 240.20. Mean specific conductance of 526 µS/cm was higher at the Henry Miller Water District pump-in. These values were about equal or lower than Aqueduct levels where mean specific conductance at Check 21 was 752 and 766 µS/cm during 1991 and 1992, respectively (Table A-9). These pump-ins had no detectable effect on Aqueduct conductivity levels.

Wheeler Ridge pump-ins (Check 29 to Check 41) had specific conductance values higher than those in the Aqueduct at Check 29 (Figure 18). Mean conductivity of pump-ins was 1133 µS/cm (n=850) compared to Aqueduct specific conductance of about 730 at Check 29 during 1991 and 1992. Although pump-in conductivity was higher than Aqueduct levels, there was no detectable increase in conductance down aqueduct of the pump-ins at Check 41.

AVEK pump-ins (below Check 41) had lower levels of specific conductance than the Aqueduct. Mean conductivity of the pump-ins was 468 µS/cm (n=43) compared to mean Aqueduct values at Check 41 of 732 and 759 µS/cm during 1991 and 1992, respectively. Aqueduct conductivity values decreased at Devil Canyon compared to Check 41. However, the decrease could not be attributed to pump-ins since conductivity at Devil Canyon were similar in 1991 (AVEK pump-in) and 1992 (no pump-in).

Figure 18

Monthly specific conductance in the aqueduct, 1989 — 1992



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Appendix A

Monthly Water Quality Values at Selected Stations from 1989 — 1992

Appendix A

Mean monthly and annual water quality values are presented for arsenic, selenium, nitrate, chloride, hardness, sodium, sulfate, total dissolved solids, and specific conductance. Data from 1989 through 1992 is given for the seven stations listed below with the DWR station code shown in italics.

Abbrev	Description	Milepost
Banks	Harvey O. Banks Banks Pumping Plant — *KA000331*	3.31
DMC	Delta Mendota Canal at O'Neill Pump Generation Plant — *DMC06930*	—
Check 13	California Aqueduct at O'Neill Forebay Outlet — *KA007089*	70.89
Check 21	California Aqueduct near Kettleman City — *KA017226*	172.26
Check 29	California Aqueduct — *KA024454*	244.54
Check 41	California Aqueduct — *KA030341*	303.41
Devil Cyn	California Aqueduct at Devil Canyon Afterbay— *KA041288*	412.88

Monthly and annual mean arsenic and selenium concentrations were calculated for nondetectable values (< 0.001 mg liter $^{-1}$) by assuming the value was equal to the detection limit. Values denoted by (●) indicate that no sample was collected in that month.

Tables A-1 through A-9 follow

Table A-1
Arsenic (mg liter $^{-1}$), 1989 — 1992

Date	Banks	DMC	Check 13	Check 21	Check 29	Check 41	Devil Cyn
Jan-89	0.002	•	0.002	0.002	•	< 0.010[a]	•
Feb-89	0.002	•	0.002	0.002	•	< 0.010[a]	•
Mar-89	0.002	•	0.002	0.002	•	< 0.010[a]	•
Apr-89	0.002	•	0.002	0.002	•	< 0.010[a]	•
May-89	0.002	•	0.002	0.002	•	< 0.010[a]	•
Jun-89	0.002	•	0.002	0.002	< 0.010[a]	< 0.010[a]	< 0.010[a]
Jul-89	< 0.001	•	0.001	< 0.001	< 0.010[a]	< 0.010[a]	< 0.010[a]
Aug-89	0.002	•	0.002	0.002	< 0.010[a]	< 0.010[a]	< 0.010[a]
Sep-89	0.002	•	0.002	0.002	< 0.010[a]	< 0.010[a]	< 0.010[a]
Oct-89	0.002	•	0.002	0.002	< 0.010[a]	< 0.010[a]	< 0.010[a]
Nov-89	0.002	•	0.002	0.002	< 0.010[a]	< 0.010[a]	< 0.010[a]
Dec-89	0.002	•	0.002	0.002	< 0.010[a]	< 0.010[a]	•
Jan-90	0.001	•	0.002	0.002	< 0.010[a]	< 0.010[a]	•
Feb-90	0.001	•	0.002	0.002	< 0.010[a]	< 0.010[a]	< 0.010[a]
Mar-90	0.002	•	0.002	< 0.001	< 0.010[a]	0.002	0.002
Apr-90	0.002	0.002	0.002	0.002	0.002	0.002	0.002
May-90	0.002	0.002	0.002	0.001	0.002	0.002	0.002
Jun-90	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Jul-90	0.003	0.002	0.002	0.002	0.002	0.002	0.002
Aug-90	0.003	0.002	0.002	0.002	0.002	0.002	0.002
Sep-90	0.003	0.002	0.002	0.002	0.003	0.002	0.002
Oct-90	0.002	0.003	0.003	0.003	0.002	0.003	0.003
Nov-90	0.002	0.003	0.003	0.002	0.006	0.003	0.003
Dec-90	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Jan-91	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Feb-91	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Mar-91	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Apr-91	0.002	0.002	0.002	0.002	0.018	0.003	< 0.001
May-91	0.002	0.002	0.002	0.003	0.009	0.006	< 0.001
Jun-91	0.002	0.002	0.002	0.002	0.003	0.003	0.004
Jul-91	0.003	0.004	0.003	0.003	0.003	0.003	0.004
Aug-91	0.002	0.003	0.004	0.002	0.003	0.003	0.004
Sep-91	0.002	0.003	0.003	0.003	0.004	0.004	0.003
Oct-91	0.002	< 0.001	0.003	0.003	0.004	0.004	0.004
Nov-91	0.002	0.002	0.002	0.003	0.005	0.003	0.003
Dec-91	0.002	•	0.002	0.002	0.003	0.003	0.004
Jan-92	0.002	0.002	0.002	0.002	0.003	0.002	0.004
Feb-92	0.002	•	0.002	0.003	0.006	0.006	0.004
Mar-92	•	0.002	0.002	0.003	0.003	0.005	0.002
Apr-92	0.002	0.002	0.002	0.002	0.003	0.003	< 0.001
May-92	0.003	0.002	0.002	0.003	< 0.001	0.002	0.003
Jun-92	0.003	0.003	0.002	0.002	0.002	0.001	0.003
Jul-92	0.003	0.003	0.002	0.002	0.002	0.002	0.002
Aug-92	0.003	0.002	0.003	0.002	0.002	0.002	0.002
Sep-92	0.002	0.002	0.003	0.003	0.003	0.003	0.003
Oct-92	0.002	0.002	0.003	0.003	0.004	0.003	0.003
Nov-92	0.003	0.003	0.003	0.004	0.004	0.004	0.003
Dec-92	< 0.001	0.002	0.002	0.003	0.004	0.002	0.003
Mean							
1989	0.002	•	0.002	0.002	0.010[a]	0.010[a]	0.010
1990	0.002	0.002	0.002	0.002	0.004	0.004	0.003
1991	0.002	0.002	0.002	0.002	0.005	0.003	0.003
1992	0.002	0.002	0.002	0.003	0.003	0.003	0.003

[a] - Reporting level for these samples

Table A-2

Selenium (mg liter $^{-1}$), 1989 — 1992

Date	Banks	DMC	Check 13	Check 21	Check 29	Check 41	Devil Cyn
Jan-89	< 0.001	•	< 0.001	< 0.001	•	•	•
Feb-89	< 0.001	•	< 0.001	< 0.001	•	•	•
Mar-89	< 0.001	•	< 0.001	< 0.001	•	•	•
Apr-89	< 0.001	•	< 0.001	< 0.001	•	•	•
May-89	< 0.001	•	< 0.001	< 0.001	•	•	•
Jun-89	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Jul-89	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Aug-89	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sep-89	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Oct-89	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Nov-89	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Dec-89	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	•
Jan-90	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	•
Feb-90	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mar-90	< 0.001	•	< 0.001	< 0.001	•	< 0.001	< 0.001
Apr-90	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
May-90	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Jun-90	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Jul-90	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Aug-90	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sep-90	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Oct-90	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Nov-90	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Dec-90	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Jan-91	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Feb-91	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mar-91	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Apr-91	< 0.001	0.001	0.001	0.001	< 0.001	< 0.001	< 0.001
May-91	< 0.001	< 0.001	< 0.001	0.002	< 0.001	< 0.001	< 0.001
Jun-91	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Jul-91	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Aug-91	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sep-91	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Oct-91	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Nov-91	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Dec-91	< 0.001	•	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Jan-92	< 0.001	0.002	0.001	0.001	< 0.001	< 0.001	< 0.001
Feb-92	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mar-92	•	< 0.001	< 0.001	< 0.001	0.002	< 0.001	< 0.001
Apr-92	< 0.001	0.002	< 0.001	< 0.001	0.001	< 0.001	< 0.001
May-92	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Jun-92	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Jul-92	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Aug-92	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Sep-92	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Oct-92	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Nov-92	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Dec-92	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mean							
1989	0.001	•	0.001	0.001	0.001	0.001	0.001
1990	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1991	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1992	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table A-3

Nitrate (mg liter $^{-1}$), 1989 — 1992

Date	Banks	DMC	Check 13	Check 21	Check 29	Check 41	Devil Cyn
Jan-89	•	•	•	•	•	6.8	3.4
Feb-89	•	•	•	•	•	4.8	4.0
Mar-89	•	•	•	•	•	4.0	4.3
Apr-89	•	•	•	•	•	3.6	3.5
May-89	•	•	•	•	•	3.6	4.1
Jun-89	•	•	•	•	•	3.0	3.3
Jul-89	•	•	•	•	•	3.8	3.1
Aug-89	•	•	•	•	•	0.9	2.0
Sep-89	•	•	•	•	0.9	2.1	1.6
Oct-89	•	•	•	•	•	5.1	2.3
Nov-89	•	•	•	•	•	2.7	2.6
Dec-89	2.8	•	3.5	3.7	•	3.3	•
Jan-90	•	•	•	•	•	6.0	•
Feb-90	•	•	•	•	•	5.0	4.0
Mar-90	•	•	•	•	•	5.1	5.1
Apr-90	•	•	•	•	•	•	•
May-90	•	•	•	•	•	•	•
Jun-90	•	•	•	•	•	•	•
Jul-90	•	•	•	•	•	•	•
Aug-90	•	•	•	•	•	•	•
Sep-90	•	•	•	•	•	•	•
Oct-90	•	•	•	•	•	•	•
Nov-90	•	•	•	•	•	•	•
Dec-90	•	•	•	•	•	•	•
Jan-91	•	•	•	•	•	•	•
Feb-91	4.0	8.0	4.8	5.3	5.5	•	•
Mar-91	4.5	5.0	4.7	4.2	1.8	1.8	3.8
Apr-91	5.1	4.0	5.6	4.3	1.3	1.6	1.4
May-91	2.9	3.6	3.7	4.4	2.4	1.7	2.9
Jun-91	2.5	4.0	3.9	3.9	3.1	3.6	1.5
Jul-91	3.6	3.3	3.2	4.0	3.7	2.9	2.3
Aug-91	1.2	2.1	2.9	3.6	4.2	3.1	3.6
Sep-91	0.4	2.0	0.7	2.5	•	1.5	2.7
Oct-91	1.4	2.6	1.2	1.8	2.2	2.8	3.6
Nov-91	2.6	4.7	2.9	2.2	2.5	3.2	3.3
Dec-91	4.1	5.2	3.8	3.6	3.4	3.2	2.7
Jan-92	3.2	5.2	5.4	4.8	4.3	3.3	2.4
Feb-92	10.0	12.0	5.5	5.2	4.7	4.9	3.8
Mar-92	5.1	8.4	7.1	3.1	2.9	3.8	1.9
Apr-92	1.8	3.3	3.8	5.1	5.0	2.2	0.5
May-92	0.8	3.0	4.2	4.7	4.5	4.3	3.8
Jun-92	1.9	4.6	5.0	4.5	4.1	5.2	4.7
Jul-92	0.7	3.5	4.3	4.2	3.8	4.0	3.8
Aug-92	0.8	2.2	3.0	3.7	3.7	3.5	3.9
Sep-92	1.2	2.6	1.6	2.2	1.5	2.7	3.3
Oct-92	1.6	2.7	1.3	1.7	0.8	1.6	2.7
Nov-92	2.2	3.3	2.1	2.2	1.2	1.8	2.3
Dec-92	4.8	5.3	3.8	2.6	2.0	2.4	2.2
Mean							
1989	•	•	•	•	•	3.6	3.1
1990	•	•	•	•	•	5.4	4.6
1991	2.9	4.0	3.4	3.6	3.0	2.5	2.8
1992	2.8	4.7	3.9	3.6	3.2	3.3	2.9

Table A-4

Chloride (mg liter $^{-1}$), 1989 — 1992

Date	Banks	DMC	Check 13	Check 21	Check 29	Check 41	Devil Cyn
Jan-89	102	•	114	119	142	163	148
Feb-89	164	•	163	134	126	106	142
Mar-89	103	•	114	137	144	146	134
Apr-89	22	•	38	47	36	36	109
May-89	28	•	61	121	124	122	64
Jun-89	40	•	117	117	108	103	85
Jul-89	42	•	110	109	105	107	96
Aug-89	52	•	75	66	78	71	96
Sep-89	96	•	79	81	78	72	72
Oct-89	86	•	72	67	67	63	85
Nov-89	113	•	104	98	97	106	84
Dec-89	131	•	123	134	133	134	•
Jan-90	137	•	128	137	136	130	•
Feb-90	84	•	94	102	108	113	114
Mar-90	73	•	76	88	93	88	101
Apr-90	151	116	135	132	123	120	94
May-90	143	113	113	113	112	118	125
Jun-90	112	108	107	107	109	108	113
Jul-90	58	105	107	107	125	115	110
Aug-90	87	96	113	104	102	105	104
Sep-90	70	67	93	74	70	74	100
Oct-90	117	106	108	105	87	104	86
Nov-90	150	153	140	134	132	136	•
Dec-90	175	160	168	157	156	•	•
Jan-91	142	139	149	179	170	•	•
Feb-91	155	179	155	147	150	•	•
Mar-91	128	95	131	132	146	139	134
Apr-91	37	33	74	123	68	123	43
May-91	54	60	61	101	121	126	49
Jun-91	120	106	115	117	96	111	122
Jul-91	124	132	136	139	131	137	127
Aug-91	102	92	116	128	134	139	135
Sep-91	100	117	99	115	115	94	120
Oct-91	18	81	99	102	93	99	115
Nov-91	122	122	107	86	93	82	105
Dec-91	162	151	134	127	117	117	105
Jan-92	142	125	154	148	125	128	98
Feb-92	124	98	128	119	129	119	94
Mar-92	41	143	68	129	113	118	45
Apr-92	43	68	66	59	67	132	5
May-92	55	59	95	101	94	94	88
Jun-92	123	121	105	100	104	105	95
Jul-92	154	149	106	106	107	107	102
Aug-92	161	156	121	108	112	112	111
Sep-92	144	150	153	134	123	117	112
Oct-92	151	141	132	138	143	145	134
Nov-92	159	149	133	119	119	120	131
Dec-92	153	154	142	133	118	125	124
Mean							
1989	82	•	98	103	103	102	101
1990	113	114	115	113	113	110	105
1991	105	99	114	124	119	117	106
1992	121	126	117	116	113	119	95

Table A-5

Hardness (mg liter $^{-1}$), 1989 — 1992

Date	Banks	DMC	Check 13	Check 21	Check 29	Check 41	Devil Cyn
Jan-89	132	•	145	150	162	158	151
Feb-89	146	•	169	161	142	128	144
Mar-89	119	•	134	145	140	150	138
Apr-89	66	•	81	94	84	77	125
May-89	81	•	•	141	130	132	95
Jun-89	84	•	134	134	122	121	114
Jul-89	81	•	144	142	125	125	118
Aug-89	70	•	94	78	92	85	114
Sep-89	100	•	103	98	102	102	94
Oct-89	103	•	96	92	98	92	104
Nov-89	109	•	103	100	99	105	103
Dec-89	146	•	125	134	123	120	•
Jan-90	111	•	125	134	141	142	•
Feb-90	96	•	117	124	133	130	121
Mar-90	92	•	108	117	125	112	122
Apr-90	115	150	132	132	119	118	121
May-90	111	114	126	129	119	118	122
Jun-90	109	121	119	119	121	•	•
Jul-90	82	112	112	112	121	•	•
Aug-90	87	96	119	112	112	•	•
Sep-90	98	94	105	98	94	•	•
Oct-90	118	116	119	124	109	•	•
Nov-90	136	173	132	129	129	•	•
Dec-90	145	150	147	150	143	•	•
Jan-91	139	148	152	163	157	•	•
Feb-91	143	214	155	160	162	•	•
Mar-91	120	112	148	153	162	178	143
Apr-91	96	94	113	193	110	172	104
May-91	108	114	116	163	177	156	101
Jun-91	154	142	140	141	132	139	147
Jul-91	118	143	142	147	141	141	142
Aug-91	100	100	133	148	147	151	151
Sep-91	95	143	107	135	141	131	151
Oct-91	84	109	106	127	121	131	147
Nov-91	114	132	115	113	124	127	138
Dec-91	142	145	164	143	136	133	131
Jan-92	127	186	156	176	153	153	124
Feb-92	155	167	153	158	154	159	127
Mar-92	102	240	129	167	163	146	102
Apr-92	97	138	127	124	131	142	76
May-92	114	137	133	139	129	133	134
Jun-92	134	173	136	136	139	139	140
Jul-92	133	158	139	141	142	142	142
Aug-92	126	135	144	144	139	146	146
Sep-92	110	133	127	147	131	155	152
Oct-92	123	137	129	131	129	127	150
Nov-92	137	140	141	155	150	153	143
Dec-92	170	190	142	154	141	151	143
Mean							
1989	103	•	121	122	118	116	118
1990	108	125	122	123	122	124	121
1991	118	125	132	149	142	146	136
1992	127	161	138	147	142	146	132

Table A-6

Sodium (mg liter $^{-1}$), 1989 — 1992

Date	Banks	DMC	Check 13	Check 21	Check 29	Check 41	Devil Cyn
Jan-89	68	•	75	81	86	99	88
Feb-89	95	•	98	92	82	70	86
Mar-89	70	•	75	84	88	90	84
Apr-89	18	•	28	36	27	28	74
May-89	28	•	44	79	83	82	47
Jun-89	32	•	78	78	70	67	60
Jul-89	32	•	76	75	70	72	64
Aug-89	36	•	52	45	51	47	64
Sep-89	61	•	63	55	50	45	50
Oct-89	59	•	50	47	45	46	57
Nov-89	71	•	65	62	63	70	57
Dec-89	93	•	82	88	79	84	•
Jan-90	82	•	83	89	87	84	•
Feb-90	52	•	64	70	74	75	73
Mar-90	49	•	54	62	62	57	66
Apr-90	90	77	84	83	77	80	60
May-90	86	72	77	78	74	78	83
Jun-90	71	70	70	69	74	76	78
Jul-90	40	69	69	70	76	80	74
Aug-90	56	62	74	68	65	69	72
Sep-90	48	46	61	52	48	53	65
Oct-90	75	68	71	69	60	68	63
Nov-90	95	98	91	88	82	83	•
Dec-90	108	102	105	101	99	•	•
Jan-91	84	90	94	116	108	•	•
Feb-91	98	127	100	100	99	•	•
Mar-91	79	61	88	95	95	100	86
Apr-91	27	26	44	113	78	95	34
May-91	40	43	44	80	102	95	39
Jun-91	71	74	79	82	72	79	85
Jul-91	70	79	81	85	83	87	87
Aug-91	59	56	77	86	87	88	88
Sep-91	63	80	64	92	86	81	86
Oct-91	21	57	65	90	91	96	87
Nov-91	77	79	68	78	87	83	88
Dec-91	102	89	95	99	94	90	85
Jan-92	87	98	99	121	102	106	82
Feb-92	83	82	86	129	116	100	79
Mar-92	30	114	51	132	108	99	43
Apr-92	36	56	51	47	62	112	11
May-92	42	46	67	78	74	74	78
Jun-92	79	80	71	73	76	75	78
Jul-92	93	94	71	76	76	76	76
Aug-92	93	92	78	76	76	79	78
Sep-92	82	87	88	102	93	96	81
Oct-92	92	87	82	110	108	104	96
Nov-92	97	92	85	112	103	99	96
Dec-92	99	97	90	115	110	112	96
Mean							
1989	55	•	66	69	66	67	66
1990	71	74	75	75	73	73	70
1991	66	65	75	93	90	89	76
1992	76	85	76	97	92	94	75

Table A-7

Sulfate (mg liter $^{-1}$), 1989 — 1992

Date	Banks	DMC	Check 13	Check 21	Check 29	Check 41	Devil Cyn
Jan-89	49	•	58	66	66	68	53
Feb-89	48	•	69	68	62	58	53
Mar-89	46	•	58	59	58	60	55
Apr-89	17	•	26	29	26	28	52
May-89	22	•	33	52	62	62	44
Jun-89	27	•	50	50	50	46	44
Jul-89	20	•	50	49	47	48	47
Aug-89	17	•	29	22	29	27	41
Sep-89	26	•	33	29	28	28	30
Oct-89	32	•	28	25	24	25	32
Nov-89	33	•	37	37	37	41	28
Dec-89	67	•	46	54	41	43	•
Jan-90	34	•	48	56	59	59	•
Feb-90	30	•	47	55	56	53	46
Mar-90	29	•	40	50	59	45	52
Apr-90	36	58	37	38	46	49	50
May-90	39	43	43	43	41	51	53
Jun-90	38	43	43	44	43	48	51
Jul-90	23	39	39	40	41	48	49
Aug-90	22	26	40	36	34	44	46
Sep-90	22	22	34	32	29	31	35
Oct-90	34	37	38	40	32	46	53
Nov-90	42	72	46	46	44	39	•
Dec-90	55	60	58	62	57	•	•
Jan-91	60	63	63	75	66	•	•
Feb-91	54	123	68	78	74	•	•
Mar-91	41	38	60	90	77	106	56
Apr-91	25	25	53	149	86	98	23
May-91	33	39	41	103	140	80	27
Jun-91	38	49	53	63	59	61	62
Jul-91	34	53	55	67	61	71	73
Aug-91	27	29	51	69	74	78	76
Sep-91	25	60	36	85	78	82	75
Oct-91	16	34	28	92	97	107	74
Nov-91	38	48	38	75	88	103	81
Dec-91	54	87	54	86	89	82	79
Jan-92	42	107	66	123	105	108	76
Feb-92	67	102	71	174	130	108	73
Mar-92	33	154	59	177	154	108	40
Apr-92	33	68	60	65	85	117	•
May-92	42	55	53	74	73	71	87
Jun-92	47	74	57	67	68	66	79
Jul-92	44	59	53	63	62	67	73
Aug-92	37	43	53	64	63	68	68
Sep-92	31	41	37	95	87	101	68
Oct-92	39	54	46	98	100	89	88
Nov-92	39	40	43	121	103	112	84
Dec-92	69	71	50	116	117	113	89
Mean							
1989	34	•	43	45	44	45	44
1990	34	44	43	45	45	47	48
1991	37	54	50	86	82	87	63
1992	44	72	54	103	96	94	75

Table A-8

Total Dissolved Solids (mg liter $^{-1}$), 1989 — 1992

Date	Banks	DMC	Check 13	Check 21	Check 29	Check 41	Devil Cyn
Jan-89	340	•	382	398	385	416	377
Feb-89	428	•	481	453	399	385	430
Mar-89	336	•	378	417	384	485	521
Apr-89	137	•	182	200	182	179	367
May-89	155	•	234	374	392	373	232
Jun-89	189	•	364	360	338	308	286
Jul-89	175	•	360	354	333	328	326
Aug-89	191	•	249	216	271	227	301
Sep-89	278	•	291	269	248	274	240
Oct-89	272	•	243	229	219	191	267
Nov-89	311	•	304	294	351	329	291
Dec-89	426	•	366	388	349	386	•
Jan-90	355	•	366	399	419	423	•
Feb-90	264	•	313	343	367	355	341
Mar-90	250	•	283	312	325	323	320
Apr-90	375	372	364	359	356	375	310
May-90	385	342	336	334	•	333	426
Jun-90	350	349	346	344	350	376	421
Jul-90	218	324	326	326	360	351	318
Aug-90	248	272	327	307	305	304	307
Sep-90	237	234	286	260	244	231	277
Oct-90	340	312	318	313	281	243	226
Nov-90	398	460	383	377	375	328	•
Dec-90	466	460	478	458	448	•	•
Jan-91	415	419	438	500	480	•	•
Feb-91	432	598	459	469	462	•	•
Mar-91	363	304	420	446	445	481	399
Apr-91	194	184	301	529	357	455	209
May-91	233	259	260	422	502	448	225
Jun-91	342	375	384	402	361	394	418
Jul-91	323	376	389	408	391	408	401
Aug-91	264	257	368	413	422	417	413
Sep-91	276	373	280	406	389	366	426
Oct-91	160	287	291	397	404	428	426
Nov-91	340	364	312	348	382	388	403
Dec-91	437	497	395	435	417	409	403
Jan-92	387	483	444	524	468	480	378
Feb-92	417	445	426	562	513	454	361
Mar-92	208	602	305	567	512	453	238
Apr-92	213	312	290	284	338	494	130
May-92	238	274	339	380	353	360	372
Jun-92	366	416	356	363	371	376	378
Jul-92	413	445	357	373	373	374	378
Aug-92	420	422	378	373	379	384	388
Sep-92	346	384	382	453	419	436	390
Oct-92	378	383	367	444	441	434	431
Nov-92	406	400	386	486	457	474	427
Dec-92	457	477	399	489	470	479	434
Mean							
1989	270	•	320	329	321	323	331
1990	324	347	344	344	348	331	327
1991	315	358	358	431	417	419	372
1992	354	420	369	441	424	433	359

Table A-9

Specific Conductance (μSiemens cm^{-1}), 1989 — 1992

Date	Banks	DMC	Check 13	Check 21	Check 29	Check 41	Devil Cyn
Jan-89	587	•	651	688	745	815	738
Feb-89	779	•	835	759	686	605	710
Mar-89	586	•	654	729	648	745	709
Apr-89	223	•	302	343	285	286	602
May-89	267	•	415	670	658	648	409
Jun-89	322	•	654	649	608	576	507
Jul-89	310	•	639	633	582	596	548
Aug-89	327	•	450	394	427	406	533
Sep-89	510	•	531	472	418	386	422
Oct-89	505	•	453	426	359	397	480
Nov-89	577	•	560	542	504	542	425
Dec-89	745	•	652	699	663	630	•
Jan-90	656	•	666	719	646	639	•
Feb-90	478	•	559	610	653	635	618
Mar-90	445	•	499	552	544	511	568
Apr-90	706	668	678	669	651	608	521
May-90	698	618	613	612	•	607	622
Jun-90	615	619	618	619	619	602	615
Jul-90	385	578	586	586	645	618	614
Aug-90	461	509	604	563	562	558	571
Sep-90	423	421	526	463	438	460	538
Oct-90	619	584	595	584	523	584	519
Nov-90	738	843	724	705	688	702	•
Dec-90	840	815	831	810	795	•	•
Jan-91	751	761	793	901	867	•	•
Feb-91	782	1050	826	827	826	•	•
Mar-91	666	553	747	790	805	838	728
Apr-91	322	311	513	879	596	796	361
May-91	407	447	448	711	851	781	393
Jun-91	610	659	683	704	626	688	732
Jul-91	598	683	691	702	692	722	718
Aug-91	494	482	660	725	735	741	737
Sep-91	531	685	526	713	688	641	738
Oct-91	267	514	543	694	693	722	727
Nov-91	635	669	580	615	666	668	702
Dec-91	805	878	717	766	737	725	704
Jan-92	709	843	809	922	806	836	665
Feb-92	728	750	746	924	871	791	643
Mar-92	351	1000	522	952	863	788	410
Apr-92	370	546	507	487	567	848	197
May-92	433	492	560	663	623	629	641
Jun-92	677	756	631	638	657	659	659
Jul-92	753	785	639	661	665	663	665
Aug-92	736	750	677	662	666	682	676
Sep-92	667	723	722	804	741	766	693
Oct-92	716	711	676	792	793	785	764
Nov-92	766	748	706	830	795	818	771
Dec-92	827	856	741	857	816	839	768
Mean							
1989	478	•	566	584	549	553	553
1990	589	•	625	624	615	593	576
1991	572	592	644	752	732	732	654
1992	644	747	661	766	738	759	629

Appendix B

DWR Policy on Acceptance of Non-Project Ground Water Inflow to the State Water Project During Periods of Entitlement Deficiency

DEPARTMENT OF WATER RESOURCES
Policy on Acceptance of Non-Project Ground Water Inflow
to the State Water Project During Periods
of Entitlement Deficiency
Original June 1990
Amended March 1991
Amended March 1992
Amended March 1993

This policy is effective from March 1, 1993 through February 28, 1994, except as may be amended.

Non-Project ground water may be considered by the Department of Water Resources for acceptance into State Water Project facilities (including the San Luis Canal) during years when SWP water contractors or federal San Luis Canal contractors have taken significant entitlement deficiencies, as judged by DWR.

DWR may accept Non-Project water into SWP facilities provided that its acceptance will not result in the significant degradation of SWP water quality, toxicity to fish and wildlife, or adverse changes in the suitability of the water for its beneficial uses, including municipal, industrial, agricultural, or recreational purposes. No such water shall be accepted under any arrangement that would hinder the operation of the SWP to fulfill its stated purposes, or which would result in additional, unreimbursed cost of SWP or SWP contractors operations.

SPECIFIC PROVISIONS

Non-Project water shall meet the water quality criteria specified in Table 1 at the point of input into the State Water Project. Blending of multiple ground water sources to meet these standards prior to input into the SWP is acceptable. Water diverted from the SWP shall not be used for blending purposes.

Prior to Non-Project water being accepted into the SWP, the proponent of the proposed arrangement shall provide to DWR completed water quality analyses for the constituents listed in Table 1. Analyses shall be performed on each well to be pumped into the SWP, by a Department of Health Services certified laboratory. The analytical methods shall be those used for drinking water and performed by U. S. Environmental Protection Agency or DHS approved with adequate accuracy, precision, and laboratory quality control to allow comparison with the standards specified in this policy. Analytical adequacy shall be judged by DWR. When blending multiple sources, flow measurements and analytical data must show that standards are met upon input to the SWP.

Notwithstanding whether analysis indicates the quality of the proposed water meets the standards listed in Table B-1, the proponent of the arrangement shall demonstrate the source of the water to be entered into SWP facilities is of consistent, predictable, and acceptable quality. DWR shall consider each proposal on a case-by-case basis, and reserves the right to deny, modify, or terminate permission for entry of Non-Project water at its sole discretion.

If at any time the Non-Project ground water is determined by DWR not to be in compliance with the provisions of this policy, the input of that water shall cease as specified by DWR.

DWR may, at its discretion, require the operator of the arrangement to provide additional quality analyses of Non-Project ground water that is being pumped into the SWP. Also, DWR will perform or request the proponent to perform, routine water quality monitoring of Non-Project water for constituents that it deems necessary and at the frequency needed to determine any impacts to SWP water quality. DWR shall be reimbursed for reasonable costs associated with maintaining and monitoring Non- Project ground water pump-in projects.

The operator of the arrangement shall maintain accurate and current records of quantity and quality of Non-Project ground water introduced into the SWP and provide them to DWR upon request. All ground water inflow shall be metered to determine inflow quantity.

DWR shall maintain, review, and analyze water quality test results of the Non-Project inflow and will make them available to State Water Project contractors or the Department of Health Services upon request.

The foregoing policy is subject to revision or revocation at the discretion of DWR, based on establishment of new or modified drinking water criteria, emergency, or other issues of concern. SWP water contractors will be notified prior to any change in this policy.

Table B-1

WATER QUALITY CRITERIA

INORGANIC CHEMICALS

Chemical	Standard (mg/l)
Aluminum	1.0
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05[a
Mercury	0.002
Nitrate	45.0
Selenium	0.01
Silver	0.05
Fluoride	1.4-2.4[b
Specific Conductance	2,200
Total Dissolved Solids	1,500
Copper	1.0
Chloride	600
Iron	1.0
Manganese	0.2
Sulfate	600
Zinc	5.0

RADIOACTIVITY	Standard (pCi/L)
Radium-226* + Radium-228	5
Gross Alpha[c	15
Tritium*	20,000
Strontium-90*	8
Gross Beta*	50
Uranium*	20

a]Lead standard will change when DHS implements the federal standard now at .015 mg/l.
b]Depends on ambient air temperature.
c]Analyze for gross alpha; if it exceeds criteria, analyze other constituents.
d]mg/L except specific conductance which is uS/cm

Table B-1 (Continued)

ORGANIC CHEMICALS

Chemical	Standard (mg/L)
Atrazine	0.003
Bentazon	0.018
Carbofuran	0.018
Chlordane	0.0001
2,4-D	0.1
Dibromochloropropane	0.0002
Endrin	0.0002
Ethylene Dibromide	0.00002
Glyphosate	0.7
Heptachlor	0.00001
Heptachlor Epoxide	0.00001
Lindane	0.004
Methyoxychlor	0.1
Molinate	0.02
Simazine	0.01
Thiobencarb	0.07
Toxaphene	0.005
2,4,5-TP (Silvex)	0.01

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